Security Classification

UNCLASSIFIED DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

Logistics Management Institute
4701 Sangamore Road
Washington, D. C. 20016

2a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

Economic Retention Levels for Army Supply Activities

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1971	96	10

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
SD-271	LMI Task No. 70-22
b. PROJECT NO. SD-271-139	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT #1. This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	OASD(I&L)

13. ABSTRACT

The report derives three stock levels relating to long supply on hand at activities below the National Inventory Control Point (NICP) level. These are the

(1) Transfer Level (TL): the quantity on hand above which it is more economical to transfer material to another activity needing it, than to hold it; the

(2) Reporting Level (RL): the level above which stocks on hand above TL should be reported as long supply; and the

(3) Economic Retention Level (ERL): the level above which stocks on hand should be disposed of by transfer to a property disposal office, if the NICP instructs the activity to dispose of the item.

are made for all three levels.

The report recommends that:

(1) TL = the requisitioning objective (RO)
(2) RL = 2RO
(3) ERL = 3 to 8 years' supply (depending on costs and salvage value) plus safety level, plus order quantity, plus mobilization reserves.

Other recommendations include (1) not moving long supply unless it exceeds ERL, or is needed by another activity, or is causing a storage problem, and (2) granting partial reimbursement to activities transferring long supply for material between the receiving activity's RO and ERL.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

• Security Classification

ECONOMIC RETENTION LEVELS
FOR
ARMY SUPPLY ACTIVITIES

Task 70-22

June 1971

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I. SUMMARY

Task 70-22 originated in early 1970 as a result of discussions by LMI with the U. S. Army Deputy Chief of Staff for Logistics (DCSLOG) and personnel of the Army Materiel Command (AMC) concerning some of the findings of LMI Task 69-8, "Inventory Control of Army Non-Combat Essential Items." The report on Task 69-8 noted that economic retention levels (ERL) at overseas depots and direct support units (DSUs) varied widely from a low of 45 days to one or more years. The ERL apparently was not based on economic considerations and resulted in unnecessary movements of material.

During the field trips, LMI found that thousands of shipments of excess material were made daily between various activities worldwide. Many of these shipments were of low value and the material was not needed at the receiving activity. It was also found that much material was transferred to property disposal offices (PDO), where it would be sold for perhaps 5% or 10% of its original price, when instead it would have been more economical to hold the material in inventory. Improved transfer level (TL) and ERL rules would help reduce unnecessary material movements, paperwork, inventory, and costs.

The two basic objectives of Task 70-22 are to develop and propose to the Army (1) rules for determining ERLs at supply activities below the National Inventory Control Point (NICP) level and (2) methods of reporting lower level retention stocks for use in NICP decisions.

The study found that three stock levels should be established for long supply:

> Transfer Level (TL) - The quantity of material on hand above which it is more economical to transfer material to another activity needing it than to hold it, assuming that the full quantity requisitioned can be transferred. Material on hand below TL should not be moved because it is more economical to hold it until used than to incur the fixed and variable shipping costs to transfer it to another location.
>
> Reporting Level (RL) - The level above which stocks on hand above TL should be reported as long supply.
>
> Economic Retention Level (ERL) - The level above which stocks on hand should be disposed of by transfer to PDO, if the NICP instructs the activity to dispose of the item.

Currently, DoD[1] uses the two terms, TL and ERL, in the same manner as this report, but the Army[2] uses the term ERL to cover both TL and ERL. The term RL is a new term proposed by LMI. It is not used by either DoD or the Army and is implicitly assumed by them to be equal to TL.

A. Transfer Level

Two quantities need to be calculated to determine TL. First is the normal maximum amount of material which is required to be on hand. Second is the amount of material above this requirement which it is more economical to hold than to transfer. The sum of the two amounts is TL.

The Army has traditionally considered the requisitioning objective (RO) as the estimated normal maximum amount required. However, the RO is the maximum amount on hand plus on order. The

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[1]Department of Defense Directive 4100.37, "Retention and Transfer of Material Assets," September 9, 1969.

[2]Army Regulation 711-16, "DSU/Installation Stock Control and Supply Procedures (Army Field Stock Control System)," April 1966, current revision, and Army Regulation 11-8, "Army Programs-Principles, Objectives, and Policies of the Army Logistic System," August 1970.

average maximum stock actually on hand under normal conditions is the safety level (SL) plus the order quantity (Q). Therefore, normal maximum amount required to be on hand should be regarded as SL + Q, rather than RO. This is the first of the two elements in the TL calculation.

Equations to determine the quantity to retain above the normal maximum amount on hand were formulated by LMI with the variable shipping cost term expressed in pounds per unit of the item and dollar costs per pound/mile. In most cases the results, when expressed in number of months' supply, ranged from about one to four months. This amount closely approximates the order and shipping time (OST). Since SL + Q + OST = RO, a simplified decision rule, TL = RO, was developed which closely approximates the calculated optimum TL. The simplified rules does not require item weights and shipping costs, which were found to be generally unavailable.

All activities (both EOQ and non-EOQ using activities) should use the rule TL = RO. Currently, EOQ activities use TL = 2RO and non-EOQ activities use TL = RO plus one year's supply. For shelf-life material the rule should be constrained to be not more than the quantity expected to be used during the shelf-life. For items deleted from stockage lists but still in demand, the calculated RO should be used rather than the arbitrary RO of zero.

Activities are currently permitted to ship automatically to the next higher supply echelon quantities on hand above the presently defined TL without regard to whether the receiving activity needs the material. LMI recommends that material above the TL should not be moved unless it is needed by another activity. TL is a valid level only if the material transferred is needed by the receiver.

B. Reporting Level

A report of long supply should not be made unless the quantity available for transfer is large enough to avoid a shipment from some other source. The reporting level (RL) is defined as the stock level at which it is likely that the excess holding activity could fill a routine replenishment requisition with its excess. Quantities on hand above TL but below RL should not be reported as excess since it is estimated that too frequently the excess holder could not completely fill the requisitioner's order quantity, Q. Partial filling of an order and taking passing action on the balance required, or having to reorder sooner than is economic, would usually be more costly than submitting the requisition to an activity likely to fill the entire amount.

The RL consists of the sum of two quantities added to TL. First is the likely order quantity. If the quantity requisitioned to absorb some long supply cannot be shipped in full, the fixed cost of another shipment will be incurred sooner than is economic. The size requisition likely to be received from another activity for the long supply cannot be anticipated. But for transfer to another activity at the same level, it would be a reasonable assumption that the EOQ of both activities is in the same size range. There will be some variation in the quantity requested because of fluctuations in demand. Since SL covers most of these fluctuations, an additional quantity equal to SL should be held to allow for minor variations in the expected requisition quantity. Second, some quantity should be allowed for issues during the time to prepare and process the excess report and to receive a transfer requisition. The length of this time is variable, but it should approximately equal OST. Therefore, RL equals TL + Q + SL + OST, which equals twice the RO. Since RO is a

familiar number available in all inventory systems, a rule of RL = 2RO would be simple and relatively accurate to use. If any excess material is causing a storage problem, the quantity causing the problem should be identified and reported so that prompt disposition instructions can be furnished by the higher supply echelon.

The Army's current minimum line item value of excess material to be reported to an NICP is $100 overseas and $50 in CONUS. If the LMI TL and RL recommendations are adopted, there would be no need for minimum dollar constraints in RL. The RL, by definition, sets the economic minimum quantity to report, and it equals the value of one RO (RL - TL = RO).

C. Economic Retention Level

The ERL level applies only in those instances when there is a total system excess and material is to be physically disposed of as excess to Army requirements. When material is disposed of, procurement and transportation costs already incurred are lost. Additional handling and transportation costs would be incurred to dispose of the item.

ERL used at Army NICPs is well-formulated and acceptable. LMI recommends that activities below the NICP level having large capacity computers use the NICP formula, with relevant cost inputs, when they have been instructed by an NICP to dispose of an item locally. Other activities should use an ERL determined from look-up tables such as those provided in this report. It is important to note that ERL is a substantially larger quantity than TL at any echelon. When material on hand, declared excess by the NICP, is causing a storage problem, only the amount of material below the ERL that is causing the problem should be disposed of. For low cost, low annual demand items,

it is possible for ERL to be less than RL. In those situations, the item should not be reported until the quantity equals RL, and if disposition instructions are received from the NICP, the amount above ERL should be disposed of. ERL rules should apply to items deleted from stockage lists if the item is still in demand at the activity.

The current rule for ERL at the retail (below the NICP) level is RO plus three years' supply. Using the NICP formula and relevant cost inputs, ERL would range from RO plus about 3 years at high holding cost locations (e.g., Vietnam) to RO plus 8 years at low holding cost locations (e.g., CONUS installations with adequate storage facilities).

The present NICP ERL formula determines the number of years of stock to hold above the RO. The average quantity demanded per year is multiplied by the number of years in order to determine the total quantity to hold. However, the formula takes no account of losses and deterioration during the years in the holding period. An additional quantity should be added to cover the losses and deterioration. This report includes a table to illustrate this upward adjustment in the total quantity to hold.

One further adjustment in the NICP ERL policy is recommended. The additional number of years stock should be added to SL + Q rather than RO, as discussed above for TL.

D. Reimbursement Policy for Transferred Material

The report recommends that the reimbursement policy for transferred material be changed from a two stage policy (full credit or no credit) to a three stage policy of full credit for material within the receiving activity's RO or Approved Force Acquisition Objective (AFAO), partial credit for material between the receiving activity's RO (or AFAO) and ERL, and no credit for material beyond the ERL of the receiving activity.

Partial credit should be given for material between the RO (AFAO) and ERL because the material has some value for the receiver. The amount of credit should be approximately equal to the net value of the item as determined by the NICP ERL formula. The value decreases from 100% at RO to 0% at ERL.

E. Service Test

Since Army activities are currently using transfer and retention levels that are similar to the recommendations in this report, implementation of the proposed changes in rules should be relatively simple at all levels. Reporting procedures would remain essentially the same except for substituting new definitions of TL, RL, and ERL.

Table 1 shows the present DoD and Army guidelines on TL and ERL. The LMI recommendations concerning TL, RL, and ERL are included in Table 1 for comparison with current policy. LMI believes the simplicity of the changes should preclude the need for service testing, originally contemplated when Task 70-22 was issued. Therefore, it is recommended that the proposals in this report be implemented without service testing.

F. List of Recommendations

Recommendation No. 1: Change DoD Directive 7100.37 and Army Regulations 11-8 and 711-16 to set the transfer level equal to the requisitioning objective at all activities.

Recommendation No. 2: Change DOD Directive 4100.37 and Army Regulations 11-8 and 711-16 to set the reporting level (RL) at all activities equal to 2 times the requisitioning objective (RO) or the shelf-life of the item, whichever is less. When RL is exceeded, report as long supply all material on hand above RO. Where material on hand is causing a storage problem, report the amount causing the problem.

TABLE 1

TRANSFER, REPORTING AND RETENTION LEVELS
COMPARISON OF DOD AND ARMY POLICIES WITH LMI RECOMMENDATIONS
(APPROVED WAR RESERVE, WHERE APPLICABLE, IS ADDED TO QUANTITIES SHOWN)

Description	Present DOD Policy[1]	Present Army Policy[2]	LMI Recommendation
		TRANSFER LEVEL[3]	
Critical and Intensively Managed Items	RO	RO	RO
Non-Critical and Non-Intensively Managed Items	RO+ 1 year's supply[4]	RO+ 360 days expected usage[4] (for non-EOQ activities) or RO (for EOQ activities)	RO
		REPORTING LEVEL	
All Items	Transfer Level	Transfer Level	2 times Transfer Level
Minimum Value to Report	$50	CONUS: $ 50 Overseas: $100	RO
		ECONOMIC RETENTION LEVEL	
All Items	3 years' supply[7] + RO	3 years' supply.[5] Exceptions are shown below.[6] + RO	From 3 to 8 years depending on costs at each activity + SL + Q

Sources:

[1] Department of Defense Directive 4100.37, "Retention and Transfer of Material Assets," September 9, 1969.

[2] Army Regulation 711-16 "DSU/Installation Stock Control and Supply Procedures (Army Field Stock Control System)," April 1966, current revision. Exceptions are noted in Army Regulation 11-8, "Army Programs-Principles, Objectives, and Policies of the Army Logistic System," August 1970, p. 3-3.

[3] The DOD uses the term "Return Policy" to apply to retail levels. DOD retail applies only to centrally managed secondary items.

[4] Non-reparables are computed at the projected peacetime issue rate. Reparables are computed at the projected wear out rate.

[5] Applicable only when the inventory manager authorizes local disposal of a reported excess.

[6] Exceptions to policy are:

1. U.S. Army, Vietnam - 4½ months in-country, 19½ months in U.S. Army, Ryukyu Islands. (During the LMI field trip, DSUs were limited to 45 days.)
2. U.S. Army, Japan - Assets in addition to RO to cover period until scheduled depot phaseout.
3. U.S. Army Support Forces, Thailand - 12 months
4. U.S. Eighth Army, Korea - 18 months

[7] Proposed revision to DODD 4100.37 changes this to 2 to 3 years supply.

Recommendation No. 3: Change DoD Directive 4100.37 and Army Regulations 11-8 and 711-16 to require activities to hold long supply on hand until transfer instructions have been received from higher supply echelons.

Recommendation No. 4: Require supply activities to pass requisitions to a holder of long supply of the item, except when the requisitioner will pick up the item.

Recommendation No. 5: Change DoD Directive 4100.37 and Army Regulations 11-8 and 711-16 to set economic retention levels for activities below the NICP based upon the Army NICP ERL formula or simplified rules proposed in this report.

Recommendation No. 6: Change DOD Directives 4100.37 and 7420.1 to grant reimbursement to activities transferring long supply as follows:

(1) Full credit for material up to the receiving activity's RO (or AFAO).
(2) Partial credit, determined as proposed in this report, for material between the receiving activity's RO (or AFAO) and ERL.
(3) No credit for material above the receiving activity's ERL.

Recommendation No. 7: Implement the proposals in this report without service testing.

II. INTRODUCTION

A. Background

LMI Task 70-22 originated in early 1970 as a result of discussions by LMI with the U. S. Army Deputy Chief of Staff for Logistics (DCSLOG) and personnel of the Army Materiel Command (AMC), concerning the findings of LMI Task 69-8.[1] That report pointed out that economic retention levels (ERL) varied from 45 days at Vietnam DSUs to one or more years at theater depots. Material on hand above the ERL was authorized for transfer to the next higher supply echelon without prior notification or approval and without the higher echelon needing the item. This policy caused uneconomic shipments. For example, one overseas depot reported that an average of 35% of all returns from customers had line item values of less than $10, while the cost to process a return transaction exceeds $10.

B. Objectives

The two basic objectives of the study are to develop and propose to the Army (1) rules for determining economic retention stock levels at supply activities other than national inventory control point (NICP) depots and (2) methods of reporting lower level retention stocks for use in NICP decisions. The task order, included as Appendix A, also requires that proposed rules must be usable with present data and computer capability and be easy to adapt to present systems.

C. Scope

The task order is directed to activities below the NICP level and calls for explicit consideration of:

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[1] Logistics Management Institute, "Inventory Control of Army Non-Combat Essential Items," LMI Task 69-8, June 1970.

(1) workload effects,

(2) weight, cube, and dollar constraints, and

(3) variations in the cost to hold, to ship, and to dispose of inventory, depending on the stock location.

In addition, the task order states that:

(1) rules and methods will be structured with application to the other services in mind,

(2) the impact of proposals on existing and proposed DoD and Army instructions and procedures will be stated in the recommendations and service test evaluations (e.g., DoDI 4100.37 and Army Circular 700-18), and

(3) test procedures will be proposed and, if approved by the Army, will be tested at a small and large overseas supply activity, and a small and large CONUS post.

D. Organization of the Report

Following this introduction (Chapter II), the next three chapters discuss the three recommended levels for long supply - transfer level (Chapter III), reporting level (Chapter IV), and economic retention level (Chapter V). The final chapter discusses the implementation and service testing. Appendices include the task order, glossary of abbreviations, derivation of formulas used in this report, cost inputs used, and tables of detailed results.

III. TRANSFER LEVEL

A. General

Inventory systems are designed to meet expected requirements. When requirements decrease, or too much material is received, long supply develops. The unnecessary movement of such long supply, when there is no storage problem, can greatly increase costs. Therefore, the decision on whether to hold the long supply or to transfer it and reorder more when it is needed should be made on the grounds of which action costs less.

Transfer level (TL) is defined by LMI as the quantity of material on hand above which it is more economical to transfer material to another activity needing it than to hold it, assuming that the full quantity requisitioned can be transferred. If the full quantity requisitioned cannot be furnished by the holder of the long supply, the balance of the material must be ordered from another supply source and additional processing and shipping costs are incurred.

DoD Directive 4100.37[1] and Army Regulations 11-8[2] and 711-16[3] prescribe policy guidance for transfer levels and retention levels. DoD uses the term "transfer level" to apply only to wholesale supply activities, and the term "return level" to apply to retail activities. For purposes of this report, DoD's "transfer level" and "return level" are considered synonymous. The Army uses only the term "economic retention level" to cover both ERL and TL.

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[1]Department of Defense Directive 4100.37, "Retention and Transfer of Material Assets," September 9, 1969.

[2]Army Regulation 11-8, "Army Programs - Principles, Objectives, and Policies of the Army Logistic System," August 1970.

[3]Army Regulation 711-16, "DSU/Installation Stock Control and Supply Procedures (Army Field Stock Control System)," April 1966, current revision.

Table 1, on page 8, summarizes current DoD and Army policies for TL at retail supply activities. Policies of DoD and the Army are essentially identical except that the Army separates TL for non-critical material into two categories: (1) activities using EOQ and (2) activities using Economic Inventory Principle (EIP) order quantities or a specified number of days order quantity. Army EOQ activities use 2RO as TL. The DoD and the Army non-EOQ activities use RO + 1 year's supply as TL.

B. Optimum Transfer Level

It is economical to transfer material on hand above requirements to another activity only if the cost to transfer is less than the cost to hold the material where it is until needed by the holder. To determine TL, a total cost equation is set up which calculates the TL quantity producing the lowest combined cost for holding material and for fixed and variable costs of shipping it. The derivation is explained in detail in Appendix C. TL is shown to be the sum of (1) the safety level (SL), (2) the economic order quantity (Q), (3) a quantity less than half of Q, depending upon the amount of long supply on hand, and (4) a small quantity which depends on the variable cost of shipment per unit. The SL + Q quantity is used because it is the maximum amount of stock normally desired to be on hand.

Figure 1 illustrates the derivation of TL in Appendix C. The vertical axis shows the dollar cost to hold or to transfer material. The horizontal axis shows the quantity of material above the normal maximum, SL + Q, held or shipped, expressed in multiples of Q. The "cost to hold" curve includes costs of storage, deterioration, obsolescence, physical loss, and the cost of money invested in inventory. The more material that is held, the longer the period of time to reduce the quantity on hand to the normal maximum, SL + Q. This relationship produces

an exponentially increasing "cost to hold" curve. The line representing the cost to transfer includes the fixed cost of reordering and variable cost of shipping material to the activity where needed. For purposes of simplification, the "cost to transfer" curve is depicted as linear, assuming fixed costs are spread uniformly over the order quantity.

The cost of holding the extra inventory is less than the cost of shipments avoided up to .5Q above normal stock, at which level the two curves intersect. The quantity held at which the net savings (cost to transfer minus cost to hold) reaches its maximum (between .25Q and .5Q in the situation depicted by the vertical dotted line in Figure 1) is the optimum amount of material to hold above the normal maximum quantity of material on hand (SL + Q). As explained in Appendix C, this quantity falls between a minimum of approximately Q/4 and a maximum of about Q/2, depending on the quantity on hand, if variable shipping costs are small enough to be negligible. As variable shipping costs become larger, TL becomes proportionately larger.

C. Recommended Simplified Rule

A simplified TL formula was sought because weight per item[1] and shipping costs are not generally known and because it was found that variable shipping costs usually have only a small effect on the final results.

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[1] In one recent study, it was found that 1.2 million of 3.8 million Army requisitions from overseas activities on CONUS during a one-year period were for federal stock numbers for which complete price, weight, or cube information was missing from the Army Master Data File. The study was Lawrence G. Regan, et al, Economic Use of Military Airlift and Sealift for Overseas Shipment in Peacetime, Research Analysis Corporation, McLean, Virginia, February 1969, Vol. II p. 23.

FIGURE 1

ILLUSTRATION OF DERIVATION OF TRANSFER LEVEL

Quantity Held Above Normal Maximum On Hand, SL + Q

(When Variable Shipping Costs are Negligible)

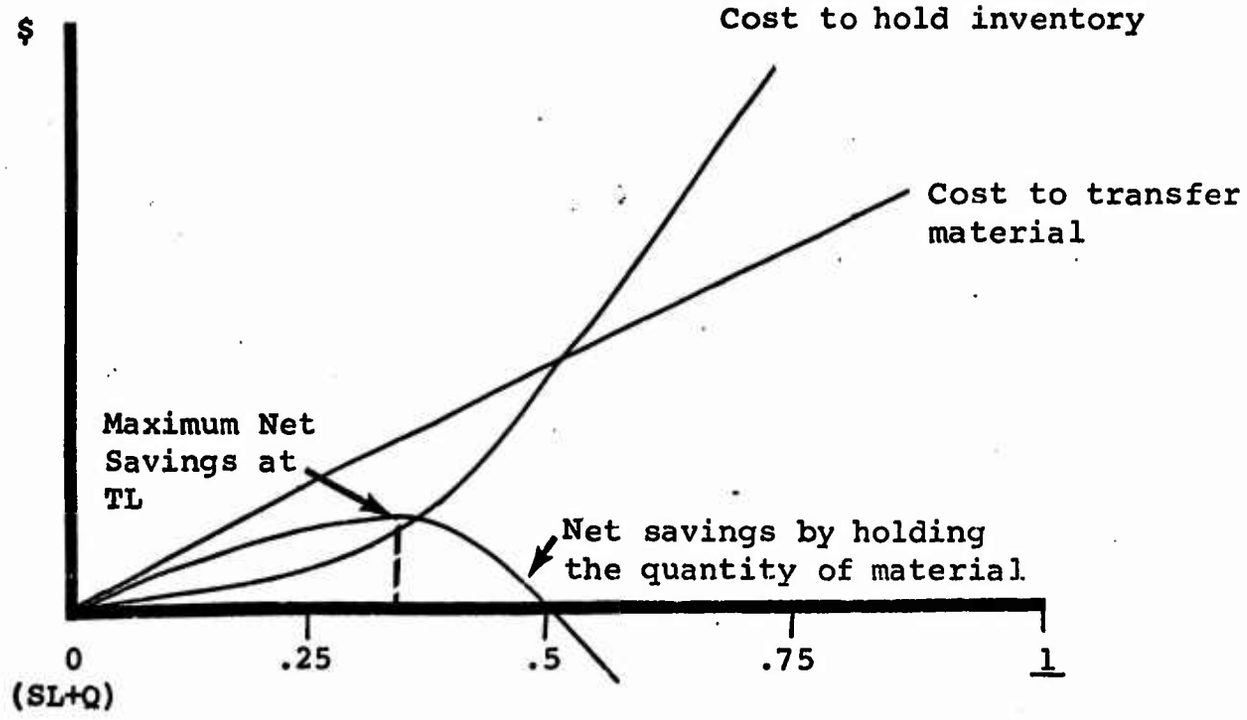

Table 2 shows the quantity of stock between the TL and the average maximum stock on hand (SL + Q). The table expresses quantity in terms of multiples of Q and number of months supply for each of three modes of transportation for replenishments - land, sea and air. Land transportation assumes the source of supply for replenishments is within the same country or continent. Sea and air transportation include those additional shipping costs, as well as relevant land transportation costs.

TABLE 2

TRANSFER LEVEL EXPRESSED AS QUANTITY OF STOCK ABOVE NORMAL ON HAND* AVERAGE COST CASE**

UNIT PRICE PER POUND	VALUE OF ANNUAL DEMAND $10	$100	$1,000	$10,000
LAND TRANSPORTATION				
	Multiples of Q			
$ .50/lb	.3	.3	.4	.7
$ 2.00/lb	.3	.3	.3	.4
	Months of Supply			
$ .50/lb	8.1	2.8	1.2	.6
$ 2.00/lb	7.8	2.5	.9	.3
SEA TRANSPORTATION				
	Multiples of Q			
$ .50/lb	.3	.4	.7	1.5
$ 2.00/lb	.3	.3	.4	.6
	Months of Supply			
$ .50/lb	14.2	5.9	3.2	2.4
$ 2.00/lb	12.7	4.4	1.7	.9
AIR TRANSPORTATION				
	Multiples of Q			
$ 5.00/lb	.3	.3	.5	1.2
$10.00/lb	.3	.3	.4	.7
	Months of Supply			
$ 5.00/lb	13.6	5.3	2.6	1.8
$10.00/lb	12.9	4.6	1.9	1.1

*Normal on hand stock is defined here as safety level (SL) plus order quantity (Q).

**Cost inputs are shown in Appendix D.

Note:

The figures in this table are results using the lower bound optimum transfer level formula (Q/4) explained in Appendix C.

Table 2 was calculated using a representative set of cost values (the average cost case described in Appendix D) and two likely values of unit price per pound are used for each of the three transportation modes. These two values for land and sea transportation, represent about 78% of the requisitions processed.[1] The two values for air transportation are higher to reflect possible air eligibility criteria[2] and represent virtually all of the eligible requisitions processed.

The table shows that for the most likely values of annual demand (above $100), the number of months supply ranges from about 1/2 to 3 months for land transportation, 1 to 6 months for sea transportation, and 1 to 5 months for air transportation. This range is close to the number of months in the normal order and ship time (OST) - approximately one month when the source of supply is close and four months for overseas shipments. If it is accepted that the quantity in OST closely approximates the optimum quantity in TL above normal maximum quantity on hand, then TL may be set equal to SL + Q + OST, which sum equals RO.

Appendices E and F provide tables showing the optimum quantity expressed in multiples of Q and months of supply, respectively, which would result from various cost inputs. Table 2 summarizes parts of the two appendices.

LMI calculated the net difference between the optimum TL (using the formula in Appendix C) and the arbitrary rule, TL = RO. Appendix G provides the detailed derivation of the formulas for calculating the net difference. Results are shown in Appendix H

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[1] Ibid.

[2] A minimum air eligibility criterion of about $3.87 unit price per pound is recommended in the Logistics Management Institute report, "Criteria For Airlift Eligibility of DOD Cargo," LMI Task 70-19, May 1971.

for the differences in terms of dollar cost between the optimum TL and two arbitrary rules: RO with OST of 1 and 4 months. Dollar cost differences for the average cost case are summarized in Table 3. The net dollar differences between the optimum rule and an arbitrary rule, TL = RO, are zero or very small in most of the relevant situations. For example, it is likely that OST for land or air transportation cases is about 1 month. The cost differences range from $0 to $13 with 13 of the 16 values less than $5. For the sea transportation case, the OST averages close to 4 months. Dollar differences range from $0 to $202, with half the values $2 or less. The dollar cost differences for any of the three transportation modes are very small for annual values of demand of $1,000 and under, regardless of whether one or four months OST is used. Therefore, LMI believes the simplified rule that TL = RO, resulting in all material above the RO being available for transfer, is sufficiently accurate to be used. All activities (both EOQ and non-EOQ activities) should use the same recommended rule.

For shelf life items, the TL (RO) should be set so that the item's shelf life has not expired before its use or transfer. The TL rule should be applied to items which are being deleted from stockage lists because of low frequency of demands. The calculated RO at the time the delete decision is made should be used rather than an arbitrary RO of zero.

Recommendation No. 1: Change DoD Directive 4100.37 and Army Regulations 11-8 and 711-16 to set the transfer level equal to the requisitioning objective at all activities.

TABLE 3

NET DOLLAR COST DIFFERENCE BETWEEN
OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE
AVERAGE COST CASE*

UNIT PRICE PER POUND	VALUE OF ANNUAL DEMAND $10	$100	$1,000	$10,000
OST = 1 MONTH OF RO				
Land Transportation				
$ .50/lb	1	1	0	3
$ 2.00/lb	1	1	0	9
Sea Transportation				
$ .50/lb	4	5	10	40
$ 2.00/lb	3	2	1	0
Air Transportation				
$ 5.00/lb	3	4	5	13
$10.00/lb	3	3	2	0
OST = 4 MONTHS OF RO				
Land Transportation				
.50/lb	0	0	10	235
$2.00/lb	0	0	20	278
Sea Transportation				
.50/lb	2	1	1	54
$2.00/lb	2	0	11	202
Air Transportation				
5.00/lb	2	0	4	102
$10.00/lb	2	0	9	177

*Cost inputs are shown in Appendix D.

NOTE:

The figures in this table use the lower bound formula (Q/4) explained in Appendix C.

IV. REPORTING LEVEL

A. General

The reporting level (RL) is defined by LMI as the quantity of material on hand above which material should be reported as excess. DOD and the Army do not explicitly use the term reporting level and assume that TL equals RL, except when the value of material on hand above TL is less than $100 for overseas activities or $50 for CONUS activities. In that case, the material is not reported and can be disposed of by the excess holder without approval from higher authority.

B. Recommended Rule

The reporting level should take account of at least two factors: (1) material normally consumed during the excess reporting processing time and (2) an assumed quantity of material which might be ordered by other customers. The explanation for these factors is as follows:

(1) During the time required to process the report of excess and receive a requisition for the material, the excess holder is likely to consume or issue some or all of the excess. If the excess is consumed before receiving a requisition for it, the requisition cannot be filled. As a result, supply responsiveness is delayed and unproductive costs are incurred. The processing time to generate a request for transfer probably equals the time required to process a routine requisition. Therefore, a quantity equal to the amount consumed in the normal OST should be allowed for in addition to TL.

(2) The TL formulation in Appendix C assumes that the transfer takes the place of a shipment from elsewhere. If the excess holding activity cannot completely fill a routine replenishment from another activity, the requisitioning activity would have to reorder earlier than normal, or right away, thereby causing higher fixed costs of ordering and shipping. In that case, the transfer would not save as much fixed shipping cost as assumed in the derivation of TL. The quantity ordered on a routine replenishment is normally the requisitioner's Q plus any amount below his reorder point. This amount below reorder point, resulting from fluctuations in demand, is provided for in the safety level (SL) stocks. Obviously, demand patterns for each federal stock number (FSN) vary among activities. For simplification, in the absence of information about the Q and SL of potential requisitioners, the best estimate by the holder of the excess is that other activities' Q and SL are about the same as its own. Such an assumption provides a workable rule for determining RL.

(3) Adding the OST quantity from (1) to the SL + Q quantities in (2) equals RO. This RO quantity, when added to TL (RO), equals 2RO. Therefore, it seems reasonable to set RL = 2RO. When RL is reached, and a report of long supply is made, the entire quantity on hand above RO, rather than just above RL, should be reported.

Under current rules at activities using EOQ, excess reports are made at the point recommended in this report (2RO), but the amount declared to be long supply is the amount above 2RO rather than the amount above RO. Activities now using the rule, RL = RO + 1 years' supply, should also change to the RL = 2RO rule. The current rule of RO + 1 year's supply requires those activities to carry more long supply for most items than that carried by activities using the 2RO rule. RL should be constrained to not exceed the quantity normally consumed during the shelf-life of the item, if this is less than 2RO.

Current DOD rules prescribe that if the value of the excess is less than $50, the excess need not be reported and can be disposed of locally. The Army minimum reporting policy is $100 for overseas activities and $50 for CONUS activities. The proposed RL rule eliminates the need for these dollar limitations because the limitations are built into the system. The value of material in one RO (RL-TL = RO) is the minimum dollar value to be reported. Where material on hand above the RO (even if below RL) causes storage problems, it should be reported promptly.

> Recommendation No. 2: Change DOD Directive 4100.37 and Army Regulations 11-8 and 711-16 to set the reporting level (RL) at all activities equal to 2 times the requisitioning objective (RO) or the shelf-life of the item, whichever is less. When RL is exceeded, report as long supply all material on hand above the RO. Report material on hand above RO, even if below RL, where the material is causing a storage problem.

Currently, activities may ship material on hand above TL to their next higher supply echelon without notifying the higher echelon and without regard to whether the higher echelon needs the material. This permissive policy causes unnecessary shipments of material, increasing workload and costs at both the shipping and receiving activity. DOD Directive 4100.37 and Army Regulations 11-8 and 711-16 should be modified to require that activities hold long supply until transfer instructions have been received from higher supply echelons.

> Recommendation No. 3: Change DOD Directive 4100.37 and Army Regulations 11-8 and 711-16 to require activities to hold long supply until transfer instructions have been received from higher supply echelons.

Supply activities receiving reports of long supply material from subordinate activities should establish automatic routines for passing requisitions from other activities for that item to the long supply holder for issue. Supply activities should refrain from making issues of these items from their own stock, except to customers who normally pick up material directly from the activity. This practice will reduce long supply stocks more quickly than does present practice.

Recommendation No. 4: Require supply activities to pass requisitions to a holder of long supply of the item, except when the requisitioner will pick up the item.

C. Constraints

Occasions may arise when constraints would have to be imposed on the quantity of material held in TL or RL to limit dollar value, weight, or cube. This could result from such circumstances as funding limitations or from lack of storage space. If the rules proposed in this report are adopted, constraints can be implemented easily by changing the value of K in the EOQ formula

$$Q = K\sqrt{D/V}.$$ [1]

Since the value of Q is directly proportional to the value of K, if an activity knows the desired money value, weight, or cube of Q, it can determine the constant which would produce the value. To use a constraint on TL (or RL), total inventory values in TL (or RL, as appropriate) are computed using various values of K, until the desired inventory value is approximated. The

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[1] The Wilson EOQ formula is $Q = K\sqrt{D/V}$, where Q = EOQ, $K = \sqrt{2F/H}$, F = fixed cost per requisition, H = holding cost as a fraction of unit price, D = annual demand in units, and V = unit price.

value is then used in subsequent calculations of Q. This automatically imposes the required constraint, changing the value of RO (TL) as well as RL. Thus, constraints can be modified by changing the constant value. The same approach can be used with weight and cube, assuming those values are known. It is a reasonable assumption that weight and cube vary approximately linearly with the value of the total inventory.

Where variable safety levels are used, the constraints will affect reorder levels as well as order quantities. The Army is studying the use of variable safety levels at all activities.

V. ECONOMIC RETENTION LEVEL

A. General

If material is held for a long enough period of time, costs of storage, physical losses, deterioration, and obsolescence will eventually exceed what it would have cost to sell the material for salvage and rebuy it later, if needed. Economic retention levels (ERL) define a quantity of material above which it is more economical to transfer the excess to a Property Disposal Office (PDO) than to retain it for future use, assuming it is needed by no other activity. No material would be transferred to PDO without authorization from the NICP. ERL, therefore, differs from the transfer level. Material below the ERL should be either retained within the Army system or sold to another government agency for credit. Material above the ERL is removed from the Army system by sale at whatever price can be obtained, or by donation or destruction.

ERL applies only to items with a predictable demand rate. ERL should also apply to items deleted from stockage lists, if the activity continues to have a demand for the item. Excess items for which recurring demand is not predicted may be retained, based upon contingency retention level (CRL) concepts of DOD and the Army. CRL policies are not based on current issue rates, but depend upon estimated mobilization requirements. Items included in CRL generally are primary items such as tanks, ships, or aircraft which are currently excess but which might be needed in a future contingency. CRL items are outside the scope of this study.

B. Present Army Rule

The Army is currently using an excellent method[1] for determining ERL at the NICP level. The method determines mathematically how many years of supply of an item should be held to minimize the combined holding, disposal, and repurchase costs of the item, when needed. The number of years to hold the material is then multiplied by the annual system demand rate to determine the total quantity to hold. Most activities below the NICP level are governed by an arbitrary ERL rule of 3 years supply, as shown in Table 1 on page 8. Under present regulations, an arbitrary "ERL" is applied to activities below the NICP level only if they have reported excesses above RL and have been instructed by the NICP to dispose of the excess by transfer to PDO.

C. Recommended Rule

The same economic considerations which govern an NICP ERL rule should also apply to activities below the NICP level. The NICP ERL determines the maximum amount of excess stock to hold in the total system. However, the costs of getting rid of part of the excess can outweigh the costs of holding it at lower supply echelons. Transferring material to PDO involves handling and shipping costs. Additional handling and shipping costs are incurred when the former excess holding activity requisitions more of the same material when needed eventually. The PDO incurs costs to store and dispose of the excess. It is also likely that PDOs at smaller or more remote locations receive less return on sales than do the larger, centrally located PDOs. Therefore, it is probably more economical to dispose of excesses at higher supply echelons and leave excesses at lower supply echelons.

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[1] The method is developed and described in a paper by Alan J. Kaplan, Economic Retention Limits, U.S. Army Logistics Management Center, Fort Lee, Virginia, June 1969.

Optimization of a disposal system in which excess would be held at points all through the system is highly complex and could involve new NICP decision rules. Such an optimization is outside the scope of the present study. It is reasonable to make a decision based on the costs that can be estimated from information available at the stocking activity. On that basis, activities below the NICP level (the subject of this study), should retain excess stock up to the quantity where the cost to hold the marginal unit at that location equals the cost if it is disposed of and later replaced.

The short range increase in total system holding costs, if activities below the NICP level are permitted to hold an ERL when the NICP is also holding an ERL, is less than might be initially expected. ERL for all items in long supply should be recalculated at each activity at least once each year to adjust for changes in demand. When a lower level supply activity holds stock up to its ERL, it will discontinue ordering that item from its next higher source of supply for about the period of time in its ERL minus reorder point unless its long supply is transferred elsewhere when needed. This will reduce the demand rate experienced by the higher supply echelons for that period of time, and the higher echelons will adjust their ERL quantity to reflect the lower demand rate. These ERL adjustments will progressively create a new stock level equilibrium within the system which should be more economic than the equilibrium created by present methods.

Using the Army NICP formula, LMI determined the number of years in the holding period for various holding cost parameters and for salvage values of 5%, 10%, and 15% of original unit price. The formula, cost parameters, and resulting number of years in the ERL are shown in Table 4. The result using current Army NICP cost estimates is marked by asterisks.

TABLE 4
UNADJUSTED ECONOMIC RETENTION LEVELS
(IN NUMBER OF YEARS)

FACTOR VALUES			.05 SALVAGE VALUE		.10 SALVAGE VALUE		.15 SALVAGE VALUE	
			STORAGE COST		STORAGE COST		STORAGE COST	
d	θ	L	.01	.04	.01*	.04	.01	.04
.02	.02	.01	14.0	9.0	12.0	8.0	10.5	7.0
.02	.02	.02	13.5	8.5	11.5	7.5	10.0	7.0
.02	.02	.05	12.0	8.0	10.0	7.0	8.5	6.0
.02	.05	.01	11.5	8.0	9.5	7.0	8.5	6.0
.05	.02	.01	11.0	7.5	9.5	6.5	8.0	6.0
.02	.05	.02	11.0	7.5	9.5	6.5	8.0	6.0
.05	.02	.02	10.5	7.0	9.0	6.5	8.0	6.0
.02	.05	.05	10.0	7.0	8.5	6.0	7.0	5.5
.05	.05	.01	9.5	6.5	8.0	6.0	7.0	5.5
.05	.02	.05	9.5	6.5	8.0	6.0	7.0	5.5
.05*	.05*	.02*	9.5	6.5	8.0*	6.0	7.0	5.0
.05	.05	.05	8.5	6.0	7.0	5.5	6.0	5.0
.02	.15	.01	5.5	4.5	5.0	4.5	4.5	4.0
.02	.15	.02	5.5	4.5	5.0	4.0	4.5	4.0
.15	.02	.01	5.5	4.5	4.5	4.0	4.5	3.5
.02	.15	.05	5.5	4.5	4.5	4.0	4.0	3.5
.05	.15	.01	5.5	4.5	4.5	4.0	4.0	3.5
.05	.15	.02	5.0	4.5	4.5	4.0	4.0	3.5
.05	.15	.05	5.0	4.5	4.5	4.0	4.0	3.5
.15	.02	.02	5.0	4.5	4.5	4.0	4.0	3.5
.15	.05	.01	5.0	4.0	4.5	4.0	4.0	3.5
.15	.02	.05	5.0	4.0	4.5	3.5	4.0	3.5
.15	.05	.02	5.0	4.0	4.5	3.5	4.0	3.5
.15	.05	.05	5.0	4.0	4.5	3.5	4.0	3.0
.15	.15	.01	4.5	3.5	3.5	3.0	3.0	3.0
.15	.15	.02	4.0	3.5	3.5	3.0	3.0	2.5
.15	.15	.05	4.0	3.5	3.5	3.0	3.0	2.5

The NICP ERL formula is used. It is:

$$D \leq \frac{(1-t\cdot d)(1-t\cdot\theta)(1-L)^t}{(1+i)^t} - S\sum_{j=1}^{t}\frac{(1-L)^j(1-j\cdot\theta)}{(1+i)^j}$$

Where:

D = Salvage Value
d = Deterioration Rate
θ = Obsolescence Rate
L = Loss Rate
S = Storage Cost Rate
t = The optimum number of years in ERL
j = Index Year

*These are considered the average values in the Kaplan paper, op. cit.

It can be seen from Table 4 that the current Army ERL rule of 3 years above RO is correct only where high holding costs and high salvage values are present. The number of years in the ERL, depending on the values of the three cost factors (deterioration, obsolescence, and physical losses), ranges from a high of 3.5 to 14 years at a 5% salvage value, to 2.5 to 10.5 years at a 15% salvage value.

As storage costs increase from 1% to 4% of unit price per year, ERL decreases about 0.5 year for high holding costs and to a maximum of 5.0 years for low holding costs. The 1% storage cost is a typical value. Salvage values typically are in the 5% to 10% range. Most likely values for the three cost factors generally lie in the middle third of the table. ERLs in that part of the table range from 3.5 to 9.5 years.

The NICP procedure for determining the amount of ERL stock to hold is to (1) determine the number of years in the ERL, (2) multiply that number of years by the annual demand, and (3) add this amount to RO minus .5 year. That approach does not take account of losses during the years the excess stock is held. In the Army ALMC Report[1], the adjustment for losses is discussed and the formula for making the adjustment is provided. However, the directive implementing ERL does not provide for making the adjustment.

Table 5 presents the adjusted ERL values. It is obtained by multiplying the unadjusted values in Table 4 by

$$\frac{1 - (1-L)^t}{L(1-L)^t}$$, where L = annual loss rate and t = ERL in number of years

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[1]Kaplan, op. cit.

TABLE 5

ADJUSTED ECONOMIC RETENTION LEVELS
(IN NUMBER OF YEARS)

FACTOR VALUES			.05 SALVAGE VALUE		.10 SALVAGE VALUE		.15 SALVAGE VALUE	
			STORAGE COST		STORAGE COST		STORAGE COST	
d	θ	L	.01	.04	.01*	.04	.01	.04
.02	.02	.01	15.1	9.5	12.8	8.4	11.1	7.3
.02	.02	.02	15.7	9.4	13.1	8.2	11.2	7.6
.02	.02	.05	17.0	10.2	13.4	8.6	11.0	7.2
.02	.05	.01	12.3	8.4	10.0	7.3	8.9	6.2
.05	.02	.01	11.7	7.8	10.0	6.8	8.4	6.2
.02	.05	.02	12.4	8.2	10.6	7.0	8.8	6.4
.05	.02	.02	11.9	7.6	10.0	7.0	8.8	6.4
.02	.05	.05	13.4	8.6	10.9	7.2	8.6	6.5
.05	.05	.01	10.0	6.8	8.4	6.2	7.3	5.7
.05	.02	.05	12.6	7.9	10.2	7.2	8.6	6.5
.05*	.05*	.02*	10.6	7.0	8.8*	6.4	7.6	5.3
.05	.05	.05	10.9	7.2	8.6	6.5	7.2	5.9
.02	.15	.01	5.7	4.6	5.2	4.6	4.6	4.1
.02	.15	.02	5.9	4.8	5.3	4.2	4.8	4.2
.15	.02	.01	5.7	4.6	4.6	4.1	4.6	3.6
.02	.15	.05	6.5	5.2	5.2	4.6	4.6	3.9
.05	.15	.01	5.7	4.6	4.6	4.1	4.1	3.6
.05	.15	.02	5.3	4.8	4.8	4.2	4.2	3.7
.05	.15	.05	5.9	5.2	5.2	4.6	4.6	3.9
.15	.02	.02	5.3	4.8	4.8	4.2	4.2	3.7
.15	.05	.01	5.2	4.1	4.6	4.1	4.1	3.6
.15	.02	.05	5.9	4.6	5.2	3.9	4.6	3.9
.15	.05	.02	5.3	4.2	4.8	3.7	4.2	3.7
.15	.05	.05	5.6	4.6	5.2	3.9	4.6	3.3
.15	.15	.01	4.6	3.6	3.6	3.1	3.1	3.1
.15	.15	.02	4.2	3.7	3.7	3.1	3.1	2.6
.15	.15	.05	4.6	3.9	3.9	3.3	3.3	2.7

Source: Table 5 values times $\frac{1-(1-L)^t}{L(1-L)^t}$ Where: L = Loss Rate
t = ERL in number of years

*These are considered the average values in the Kaplan paper, op. cit.

A loss rate of .01 produces only small adjustments, 0.5 year or less for ERL under 10 years to 1.1 years at the highest relevant unadjusted ERL value of 14.0 years. A loss rate of .02 produces adjustments ranging from .5 year or less for ERL under 6.5 years to 2.2 years at the highest unadjusted ERL value of 13.5 years. A loss rate of .05 causes large adjustments, ranging from .5 year or less for ERL under 4.0 years to 5 years for the highest unadjusted ERL of 12 years.

Activities with large capacity computers should determine their ERL by use of the NICP ERL formula with the adjustments proposed in this report. Other activities could use a table similar to Table 5 to determine their specific ERL. For simplification, at activities without large capacity computers, it might be desirable to allow high cost activities (e.g., Vietnam) to use an ERL of 3 years and low cost activities (e.g., CONUS) to use an ERL of 8 years. It should be noted that the ERL described above should be added to the normal maximum stock desired on hand, SL + Q, in determining the total stock to retain. This recommendation does not change the current requirement that supply activities report excesses and obtain approval from the NICP before they take disposal action.

For low value, low demand items, it is possible that ERL will be less than RL. Where this occurs, the same rules described above should be followed. The item should not be reported until the quantity reaches RL. Upon receipt of disposition instructions from the NICP, the amount above the ERL would be disposed of.

Implementation of the proposed rule would involve changing DOD Directive 4100.37 and Army Regulations 11-8 and 711-16 to provide a variable amount based on the Army NICP ERL formula rather

than a 3 years supply. It is suggested that the Army request an exception to DOD Directive 4100.37 in order to implement the proposal more quickly.

Two conditions which affect the quantity in ERL should be noted:

(1) When activities, such as DSUs, are required to be highly mobile, they might not be able to hold quantities up to the ERL amount shown in Table 5. Long supply up to ERL should be held if it does not cause any problems, because this is the most economic action. However, where long supply does cause a storage problem it should be promptly reported and the next higher supply echelon should provide immediate disposition instructions.

(2) At activities where there is a shortage of personnel to manage the additional material, a higher holding cost should be used in determining the ERL.

The benefits gained by increasing the ERL would more than offset the costs of holding the additional material. Adoption of this change in ERL would result in disposing of less material because ERL would increase to more than the current 3 year rule in most instances. Increasing ERL would reduce workload in requisition processing at activities holding excesses and at PDO. The proposed rules would, in the long run, also reduce new material purchases.

Recommendation No. 5: Change DOD Directive 4100.37 and Army Regulations 11-8 and 711-16 to set economic retention levels for activities below the NICP, based upon the Army NICP ERL formula or simplified rules proposed in this report.

D. Reimbursement for Material Transfers

In addition to the requirements of the task order, the additional topic of reimbursement for material transfers is addressed in this report. There are a number of conflicting policies concerning reimbursement for material transferred to other supply activities. DOD Directives 4100.37 and 7420.1[1] provide for full reimbursement for transferred material which is within the retail activity's return level[2] or the wholesaler's authorized force acquisition objective. Material in excess of the return level or AFAO is not reimburseable. The Army has a policy similar to DOD. DSA and GSA give full reimbursement for material up to two years above their RO, but no credit for material beyond that point.

LMI believes that there should be a three-stage reimbursement policy (full credit, partial credit, no credit), rather than the current two stage policy (full credit, no credit). Material transferred which is within a receiving activity's RO (or AFAO) is required, and full reimbursement should be given to the transferring activity. Material transferred beyond the receiving activity's ERL should not be reimbursed because it would cost more to hold it than it was worth. Material between RO (or AFAO) and ERL is not required, but it is more economical to hold it than to dispose of it to PDO. The value to the holder of material on hand decreases as more material is held because holding costs increase over time. The value of the material decreases

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[1] Department of Defense Directive 7420.1, "Regulations Governing Stock Fund Operations," January 26, 1967.

[2] The return level is defined as the sum of the activity's approved war reserve material requirement, requisitioning objective, and either one year's worth of projected peacetime issues of non-reparable items or one year's worth of projected wearout of reparable items.

exponentially from 100% at RO (or AFAO) to 0% at ERL. It would seem reasonable to provide partial reimbursement for material between the receiving activity's RO and ERL based upon its estimated value.

The report recommends that long supply not be transferred unless it is needed by someone or is causing a storage problem where it is. If the material is needed, full value should be paid for it. If it is not needed and is causing a storgage problem, the higher supply echelon is required to either take the material causing the problem or to furnish disposition instructions. In that event, the receiving activity should pay only for what the material is worth to him.

The estimated value is the unit price times a reimbursement factor determined as follows: the numerator, a, is the difference between ERL and the average amount of stock on hand before and after the transfer; the denominator, b, is the amount of stock between RO and ERL. Figure 2 illustrates the logic of the proposal. Table 6 provides detailed examples of calculations in the three cases cited above. Case 1 covers a transfer that is a full reimbursement. Case 2 covers a transfer of partial reimbursement only. Case 3 covers a combination partial and no reimbursement.

Recommendation No. 6: Change DOD Directives 4100.37 and 7420.1 to grant reimbursement to activities transferring long supply as follows:

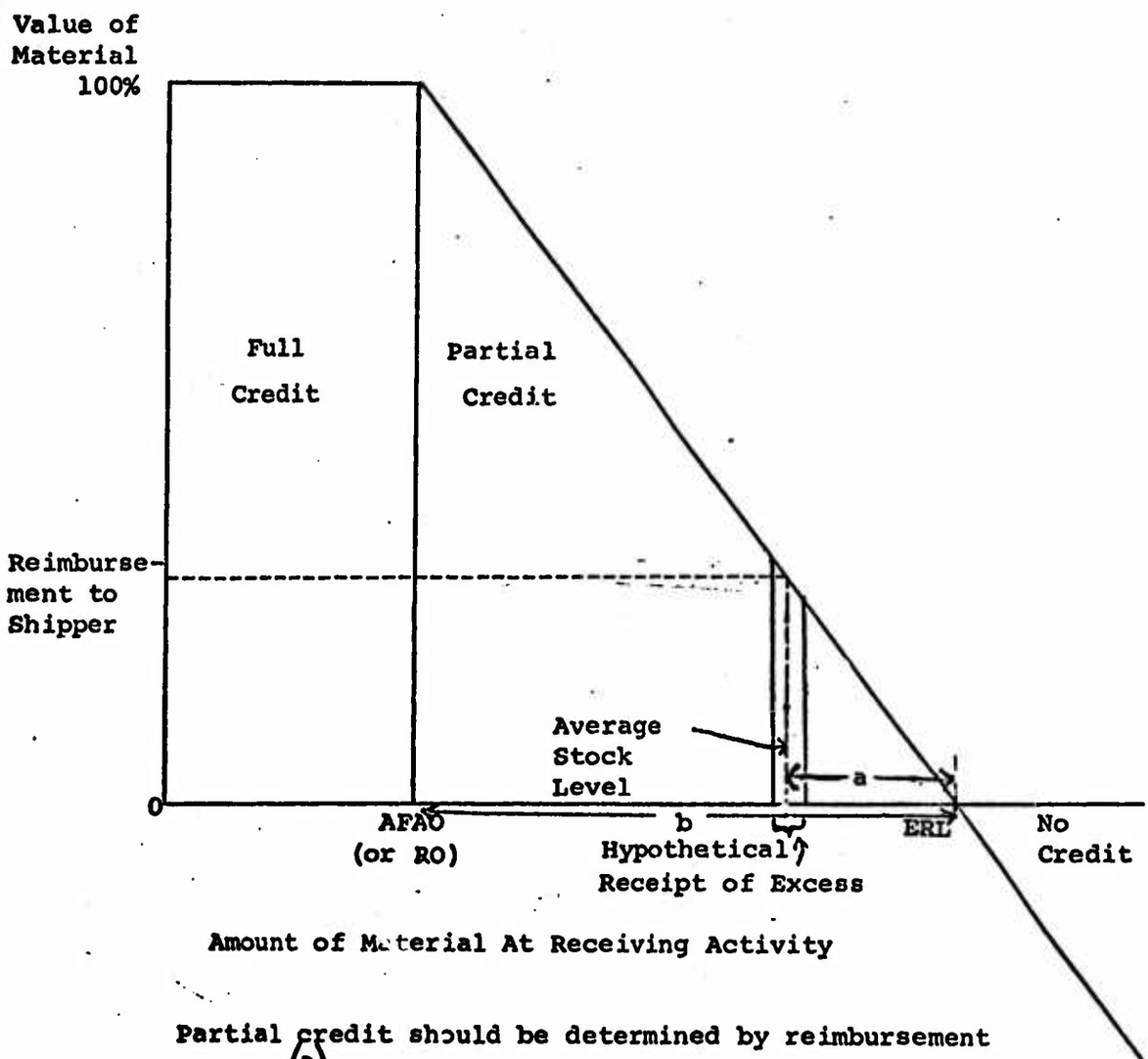
(1) Full credit for material up the receiving activity's RO (or AFAO);

(2) Partial credit, determined as proposed in this report, for material between the receiving activity's RO (or AFAO) and ERL; and

(3) No credit for material above the receiving activity's ERL.

FIGURE 2

REIMBURSEMENT POLICY



Partial credit should be determined by reimbursement factor $\left(\frac{a}{b}\right)$ times unit price.

TABLE 6

EXAMPLES OF REIMBURSEMENT FACTOR CALCULATIONS

	Activity A	Activity B		
		Case 1	Case 2	Case 3
Transfer Level (RO)	50	400	400	400
Economic Retention Level	200	1,000	1,000	1,000
On Hand	210	240	800	900
Transfer from A to B		160	160	160

Assume the item has a $2 unit price.

Case 1: Full Reimbursement

All 160 units are within the receiving activity's RO.

$2 x 160 = $320

Case 2: Partial Reimbursement

All 160 units are between the RO and ERL.

$$\frac{1,000 - (800 + 160/2)}{1,000 - 400} = \frac{120}{600} = .2$$

.2 x $2 x 160 = $64

Case 3: Partial and No Reimbursement

Only 100 of the 160 units are between RO and ERL and would receive partial reimbursement. The remaining 60 units are above ERL and would receive no credit.

$$\frac{1,000 - (900 + 100/2)}{1,000 - 400} = \frac{50}{600} = .08$$

.08 x $2 x 100 = $16

VI. IMPLEMENTATION AND SERVICE TEST

Since Army activities are currently using transfer and retention levels that are similar to the recommendations in this report, implementation of the proposed changes in rules should be relatively simple at all levels. Reporting procedures would remain essentially the same except for substituting new definitions of TL, RL, and ERL.

For EOQ activities, the effects would be as follows:

TL would be defined as equal to RO, rather than 2RO.

RL would be the same as the present TL (2RO), but the amount reported as long supply would be the amount above RO rather than the amount above 2RO. This rule applies only to reporting material available for transfer and does not apply to inventory stratification reports, which remain unchanged.

For non-EOQ activities, the effects would be:

TL would be RO, rather than RO + 1 year's supply.

RL would be 2RO, rather than RO + 1 year's supply. The amount reported as long supply would be the amount above RO rather than the amount above 2RO.

ERL for both EOQ and non-EOQ activities would change from 3 years supply to an amount between 3 and 8 years, depending upon applicable costs. Activities with large capacity computers could determine ERL based upon formulas in this report. Other supply activities could use a simplified rule of 3 years in high cost areas (e.g., Vietnam) and 8 years in low cost areas (e.g., CONUS

installations). It is recognized that many officials consider 8 years too long to hold material in long supply. However, it would be an economic policy to set ERL at that level for low cost activities. This policy would be less costly than disposing of material prematurely.

Implementation of the proposed TL, RL, and ERL rules can be accomplished easily because it only involves changing definitions in DOD Directive 4100.37 and Army Regulations 11-8 and 711-16. Pending a change in these directives, an exception could be sought to expedite implementation.

For manual record activities, a "look-up" table can be prepared which incorporates the transfer levels and reporting levels proposed in this report. The table should also include reorder points and requisitioning objectives. Table 7 is an abbreviated example of such a look-up table for one set of policy and cost parameters.

A table showing a more comprehensive range of annual demand and unit prices can be prepared for any given combination of cost parameters and inventory level policies.

Table 1 provides the present DOD and Army guidelines on TL, RL, and ERL and the LMI recommendations. LMI believes the simplicity of the changes should preclude the need for service testing, originally contemplated when Task 70-22 was issued. Therefore, it is recommended that the proposals in this report be implemented without service testing.

Recommendation No. 7: Implement the proposals in this report without service testing.

TABLE 7

EXAMPLE OF TABLE OF STOCK LEVELS

Annual Demand in Units	Stock Level	Unit Price		
		$.10	$1.00	$10.00
10	RP	2	2	2
	RO	102	32	12
	RL	204	64	24
	ERL	131	61	41
100	RP	17	17	17
	RO	337	117	47
	RL	674	234	94
	ERL	628	408	338
1000	RP	167	167	167
	RO	1167	487	267
	RL	2334	974	534
	ERL	4083	3403	3183

Where:

RP = reorder level = SL + OST

RO = requisitioning objective = RP + Q = TL

RL = reporting level for excess material = 2RO

ERL = 3 years supply + SL + Q

Values used in this table are:

Safety level = 30 days supply

Order and shipping time = 30 days

Holding costs = .20

Fixed cost to order or ship = $10.00

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APPENDIX A

ASSISTANT SECRETARY OF DEFENSE
Washington, D. C.

Installations and Logistics DATE: 31 March 1970

TASK ORDER SD-271-139
(TASK 70-22)

1. Pursuant to Articles I and III of the Department of Defense Contract No. SD-271 with the Logistics Management Institute, the Institute is requested to undertake the following task:

A. TITLE: Economic Retention Levels for Army Supply Activities

B. SCOPE OF WORK: Proposed rules for determining retention stock levels at supply activities other than NICP depots, and methods of reporting lower level retention stocks for use in NICP decisions will be developed and proposed to the Department of the Army. Explicit consideration will be given to workload effects, weight, cube, and dollar constraints, and to variations in the cost to hold, to ship, and to dispose of inventory, depending on the stock location. The proposed rules must be usable with present data and computer capability and be easy to adapt to present systems. They will be structured with application to the other services in mind. The impact of proposals on existing and proposed Army and DoD instructions and procedures will be stated in the recommendations and service test evaluations (e.g., DODI 4100.37 and Army Circular 700-18). Test procedures will be proposed, and if approved by the Army, will be tested at a small and large overseas supply activity, and a small and large CONUS post.

2. SCHEDULE: Procedures for a service test will be proposed for review by the Army within ten months. If testing is approved, an evaluation of the service tests including recommendations concerning expanded use of the test procedures, will be submitted within fifteen months from the date of this Task Order.

Barry Shillito

ACCEPTED Wm. F. Finan

DATE 31 March 1970

APPENDIX B

GLOSSARY OF ABBREVIATIONS

AMC	-	U.S. Army Material Command
DCSLOG	-	U.S. Army Deputy Chief of Staff for Logistics
DSU	-	Direct Support Unit
EIP	-	Economic Inventory Principle
EOQ	-	Economic Order Quantity
ERL	-	Economic Retention Level
NICP	-	National Inventory Control Point
OST	-	Order and Shipping Time
Q	-	Economic Order Quantity
RL	-	Reporting Level
RO	-	Requisitioning Objective
SL	-	Safety Level
TL	-	Transfer Level

APPENDIX C

FORMULAS FOR TRANSFER LEVEL

This appendix derives a mathematical expression for a calculated optimum level, called a "transfer level," T_c, below which it is not economic to transfer material to another activity for the purpose of reducing long supply at the shipping activity. For long supply material already on hand, the cost of shipping it to the holding activity has already been incurred. That cost cannot be affected by a new decision, and is not a factor in the analysis. If some of this material is transferred to an activity needing the material, the cost of a shipment from the holding to the receiving activity is incurred. This shipment takes the place of a shipment from the usual source (perhaps a depot) to the activity needing the material. For purposes of this analysis, the transportation cost from the excess holding activity to the excess receiving activity is assumed to be about the same as the transportation cost from the next higher supply source to either the holding or receiving activity, and the quantity so shipped at one time is assumed to be about the same from either source.

Shipment of material from an activity having an excess lowers the stock level and the net cost to hold inventory there. To hold material above the normal stock level adds to the cost to hold inventory with little regard to where it is held. Therefore, if material were shipped to an activity that did not need the material, no net reduction in holding cost would occur if the cost to hold is the same at both points. Since such a shipment would entail an extra shipping cost, no shipment of long

supply material is economic unless the receiving activity needs it, or the extra cost of keeping it at the holding activity exceeds the shipping cost. Hence, in general, no long supply should be shipped unless it is needed elsewhere, or it is causing storage problems or excessive holding costs at the holding activity.

The following terms are used in the derivation of the calculated optimum transfer level, T_c, above which it is economic to ship material to an activity needing the material.

A = annual value of demand = DV

B = price per pound = V/W

D = projected annual demand in units (a uniform demand rate)

F = fixed cost per order to order and ship material

F_c = fixed costs of shipments avoided by holding T_c instead of N

H = the cost to hold one unit one year, expressed as a percent of unit price

H_c = extra cost to hold inventory up to T_c instead of N

K_c = net extra cost of holding T_c instead of N, = $H_c - P_c$

M_c = the number of multiples of Q contained in T_c-N, the calculated optimum stock to hold above N. $M_c \approx (T_c-N)/Q$

N = normal or planned maximum stock on hand, in units, = S_L+Q

P_c = total fixed and variable shipping cost avoided by holding T_c instead of N

Q = the Wilson economic order quantity in units, $\sqrt{2FD/HV}$

R_o = requisitioning objective = R_p + Q, in units (shown as RO in the text of the report)

R_p = reorder point, in units (shown as RP in the report)

S_L = safety stock portion of the reorder point, in units (shown as SL in the report)

S = variable shipping cost per pound for an assumed average number of miles shipped

S_c = variable shipping costs saved by holding T_c instead of N

T_c = the calculated transfer level, or quantity of stock above which it is economic to ship an excess to an activity that needs the material

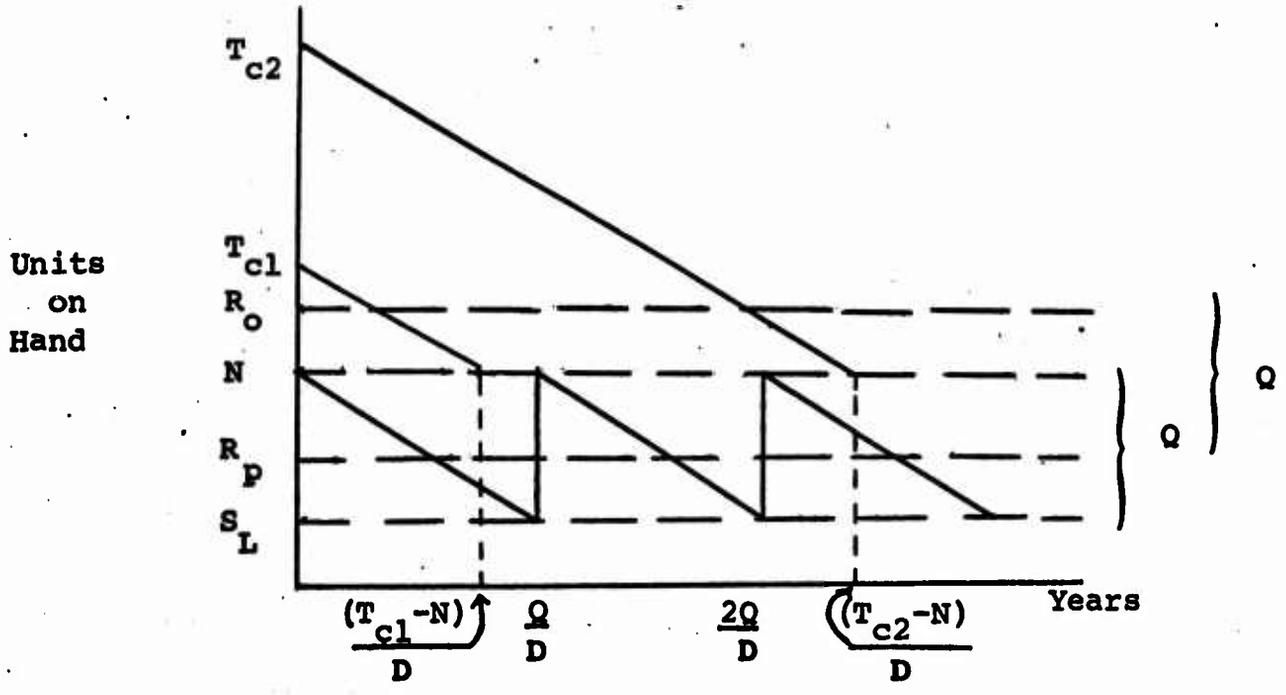
V = unit price of the item

W = weight in pounds per unit of material

A. The analysis of the cost of holding T_c rather than N is as follows, using Figure 1 to illustrate the relationships:

Figure 1

AVERAGE INVENTORY ON HAND STARTING AT DIFFERENT LEVELS



1. The average cost to hold inventory over any number of cycles is the same for any starting inventory level between R_o and N, or for starting at the level N on any date, provided the discounted value of money is ignored.

2. Holding costs can be computed as the product of (1) the average amount of long supply material held, (2) the number of years it is held, and (3) the annual cost to hold one unit.

3. A general expression for the amount of long supply would be complex, but upper and lower bounds can be stated as follows. Starting at any stock level T_c where $N < T_c \leq N + Q$, such as T_{c1}, the extra material held is $T_c - N$ until the stock level N is reached. A normal order cycle can be considered to start at that time. If $T_c > N + Q$, say T_{c2}, the average amount held has an upper bound of $(T_{c2} - S_L)/2$ and a lower bound of $(T_{c2} - N)/2$. Use of the two unique upper bounds for values of T_c above and below N + Q would narrow the range of results a little, but the extra complication is not necessary because the range with a common upper bound is acceptably small. The maximum upper bound of the average amount of material held above N, for all cases, is $T_c - N$, and the minimum lower bound is $(T_c - N)/2$, a range of Q/2.

4. The number of years the average excess is held until stock reaches N is $(T_c - N)/D$. After stock is reduced to N, the average cost per cycle to hold inventory is the same, assuming that the initial stock level is between S_L and N.

5. The cost to hold inventory one year, per unit held = HV.

6. Therefore the extra cost, H_c, to hold inventory up to the calculated optimum transfer level, T_c, has an upper bound $\overline{H}_c$, such that

(C1) $$\overline{H}_c = \frac{HV}{D}(T_c - N)^2$$

and a lower bound $\underline{H}_c$, of:

(C2) $$\underline{H}_c = \frac{HV}{2D}(T_c - N)^2$$

B. Analysis of the effect of holding T_c on fixed plus variable shipping costs, P_c, follows:

1. If stock is held up to any T_c, the extra quantity $T_c - N$ will permit avoiding a one-way shipment for each quantity Q in $(T_c - N)$. Therefore, $(T_c - N)/Q$ shipments will be avoided.

2. One-way shipping costs are the sum of fixed plus variable costs. Fixed costs are the normal administrative costs involved in requesting shipments, preparing and handling shipping documents, posting to stock records, and taking up the receipt at the receiving activity.

3. If the activity ships the quantity T_c-N, it would reach its reorder point $(T_c-N)/D$ years sooner and would place, on the average $(T_c-N)/Q$ more orders than if it had not held the stock up to T_c.

4. Therefore, the fixed cost, F_c, avoided by holding T_c is the fixed cost per shipment, F, times the number of shipments avoided, or

$$F_c = F(T_c-N)/Q$$

5. It is assumed that variable shipping cost is in proportion to the weight shipped. Since the formula should be usable at the DSU level, where shipping cost information by material category, volume, freight classification, and even weight is not usually known, equations will first be developed based only on weight. Subsequent transformations will restate the formulas in terms of value per pound, and then by simplifying assumptions will eliminate weight entirely.

6. Variable shipping costs, S_c, can be approximated by the weight per unit, W, times the shipping cost per pound for the assumed distance, S, times the number of units above N to be retained, (T_c-N), or,

$$S_c = WS(T_c-N)$$

The total reduction in cost, P_c, for new shipments to the activity by holding T_c instead of N is the sum of fixed and variable shipping costs avoided,

$$P_c = F_c + S_c$$

Substituting for F_c and S_c, and simplifying,

(C3) $$P_c = \left(\frac{F}{Q} + WS\right)\left(T_c - N\right)$$

C. The net increased cost, K_c, to retain inventory up to level T_c instead of N is the increased cost to hold T_c, which is H_c, less the shipping costs avoided, P_c, or,

$$K_c = H_c - P_c$$

For the upper bound of net costs, $\bar{K}_c$, using equations (C1) and (C3),

(C4) $$\bar{K}_c = \frac{HV(T_c - N)^2}{D} - \left(\frac{F}{Q} + WS\right)\left(T_c - N\right)$$

D. The upper bound of net costs, $\bar{K}_c$, for a given T_c sets the lower bound of the quantity, T_c, that can economically be held, designated $\underline{T}_c$. The minimum value of $\bar{K}_c$ with respect to T_c, at which the net costs, K_c, have the lowest upper bound, occurs at the lower bound of T_c, designated, $\underline{T}_c$, where,

(C5) $$\underline{T}_c = N + \frac{D}{2HV}\left(\frac{F}{Q} + WS\right)$$

E. To express $\underline{T}_c$ in terms of Q, substitute in (C5) the Wilson EOQ equation,

$$\sqrt{\frac{2DF}{HV}} = Q$$

So that

(C6) $$\underline{T}_c = N + \frac{Q}{4}\left(1 + \frac{WSQ}{F}\right)$$

Where variable shipping cost, WS, is insignificantly small, $WSQ/F \simeq 0$, and the lower bound (used in another appendix), $\underline{T}_c$, is

(C7) $$\underline{T}_c \simeq N + Q/4$$

F. Q can be expressed in terms of annual dollar demand, A, and price per pound, B. From the definitions of A and B,

$$D = A/BW$$

$$V = BW$$

Substituting for D and V in the Wilson EOQ equation,

$$Q = \sqrt{\frac{2DF}{HF}}$$ and simplifying:

$$(C8) \qquad Q = \frac{1}{WB}\sqrt{\frac{2AF}{H}}$$

Substituting (C8) for Q, in WSQ/F of (C6) and simplifying,

$$(C9) \qquad \underline{T}_c = N + \frac{Q}{4}\left(1 + \frac{S}{B}\sqrt{\frac{2A}{FH}}\right)$$

(The remaining Q in C9 will later be cancelled out in equation C10.)

Similarly the upper bound, $\overline{T}_c$, derived using $\underline{K}_c$ in the same manner is expressed by changing the term Q/4 to Q/2 in equations C6, C7, and C9.

G. For analysis and interpretation, the following relationships are useful. The optimum number of multiples of Q added to the desired inventory, N, at T_c, defined as M_c, is:

$$M_c = (T_c - N)/Q$$

For the lower bound, $\underline{T}_c$,

$$(C10) \qquad \underline{M}_c = \tfrac{1}{4}\left(1 + \frac{S}{B}\sqrt{\frac{2A}{FH}}\right)$$

The lower bound of the number of years supply, $\underline{Y}_c$, added if $\underline{T}_c$ is held instead of N, is:

$$\underline{Y}_c = \frac{Q}{4D}\left(1 + \frac{S}{B}\sqrt{\frac{2A}{FH}}\right) \qquad \text{(C11)}$$

The upper bounds $\bar{M}_c$ and $\bar{Y}_c$ are expressed by changing 4 to 2 in equations C10 and C11.

Equations C10, C11, and their upper bound counterparts will be used to examine the sensitivity of T_c to different dollars of annual demand, A, and price per pound, B. This is important because information on price per pound will frequently not be available, causing the use of an arbitrary estimate to be a practical necessity. Although annual value of demand can be calculated at activities with available computers, those with manual records would benefit by avoiding a rule that depends on the annual value of demand if this is feasible.

APPENDIX D

COST INPUTS USED IN THE ANALYSIS IN REPORT

A. Transfer Level

The report uses three sets of cost parameters, identified as low, average, and high, in analyzing the sensitivity of the transfer level (TL) to cost variations. The cost cases are believed to bracket most of the likely combinations of results. Three types of costs are involved:

(1) F - Fixed costs of ordering or shipping material, including the determination of quantity to order or ship, preparation and processing of paper work, and posting to records.

(2) S - Shipping costs per pound for the average distance shipped.

(3) H - Holding costs per year expressed as a fraction of unit price. These costs include storage costs, deterioration, obsolescence, physical losses, and interest on investment.

The symbols, F, S, and H will be used to refer to these costs. They are grouped into three transportation categories--land, sea, and air, depending on the transportation mode for routine replenishment of the excess item to the activity reporting the excess. The sea and air categories include relevant costs for the land transportation portion of the shipment. Table D-1 presents the values used in the TL analysis in Chapter III.

Values for F and H are those generally considered reasonable and are used within the Army. Shipping cost values were obtained primarily from two 1969 studies made by the Research Analysis

TABLE D-1

COST INPUTS USED IN DETERMINING TRANSFER LEVEL

COST CASE	COST PARAMETERS		
	F	H	S
		Land Transportation	
Low	7.00	.4	.005
Average	10.00	.3	.01
High	15.00	.2	.015
		Sea Transportation	
Low	10.00	.4	.02
Average	25.00	.3	.05
High	50.00	.2	.08
		Air Transportation	
Low	10.00	.4	.2
Average	25.00	.3	.35
High	50.00	.2	.5

Corporation (RAC) and the Institute for Defense Analyses (IDA). The cost values from the two studies for shipments within and between various countries are shown in Table D-2. In determining relevant values (unit price) per pound to use in the TL analysis, the frequency distribution shown in Table D-3 served as a guide. The table covers all demands (about 79 million) placed by overseas activities on CONUS during a period of about one year during 1965-1966. Although the data are for demands, rather than for material stocked, the information serves as an indication of the distribution of value per pound of Army material.

B. Economic Retention Level

Five types of costs were used for the economic retention level (ERL) analysis in Chapter V. The first four types of costs are expressed in terms of a fraction of unit price per year. The fifth is expressed as an interest rate per year.

(1) S - Storage cost

(2) d - Probable rate of deterioration

(3) θ - Probable rate of obsolescence

(4) L - Probable rate of physical loss

(5) i - Interest rate, for discounting costs and benefits to present value.

The values shown in Table D-4 are considered those most representative of present Army costs and include those used in the Kaplan paper.[1] The values were used in all 54 possible combinations (2x3x3x3) together with each of three likely disposal values (.05, .10, and .15) to produce 162 results. The i value of .10 is prescribed in DOD Instruction 7041.3.[2]

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[1]Alan J. Kaplan, Economic Retention Limits, U.S. Army Logistics Management Center, Fort Lee, Virginia, June 1969.

[2]Department of Defense Instruction 7041.3, "Economic Analysis of Proposed Department of Defense Investments," February 26, 1969.

TABLE D-2

REPRESENTATIVE SHIPPING COSTS

(In Cents Per Pound)

In Country	Commercial Rail	Commercial Highway	Military Highway	Overall
United States	.3[1]	1.2[1]		.7[1]
Europe	.4[2]	.6[2]	.3[2]	
Germany				.7[6]
Japan	.1[3]	.2[3]	.1[3]	.1[3]
Korea	.2[4]			.1[4]
Other Far East				.5[5]
Central & South America				.4[5]
Hawaii				.1[5]

CONUS To:		Sea	Air
Europe:	General Cargo	1.7[6]	
	Containerized	5.1[7]	
	Non-containerized	7.3[7]	36.0[7]
Japan:	General Cargo	2.0[6]	
	Containerized	5.4[7]	
	Non-containerized	8.2[7]	54.0[7]

Sources:

[1]Lawrence G. Regan, et al, Economic Use of Military Airlift and Sealift for Overseas Shipment in Peacetime, Research Analysis Corporation, McLean, Va., Vol. II, February, 1969.

[2]Ibid., pages 22-23

[3]Ibid., Table A12, page 24

[4]Ibid., Table A13, page 24

[5]Ibid., pages 24-25

[6]R. F. Stryker, Resupply in Peace and War By C-5 Airlift and By Containership (U), Institute for Defense Analyses, Arlington, Va., WSEG Report 141, July, 1969, Table B-19, page 121.

[7]Ibid., Table B-2, page 79

[8]Ibid., Table 2, page 9

Table D-3

FREQUENCY OF ARMY OVERSEAS DEMAND BY

UNIT PRICE PER POUND

1965 - 1966

Price Per Pound At Least	But Less Than	Frequency	Cumulative Frequency	% Cumulative Frequency
$ 0.00 -	$ 0.01	563	563	0.0
0.01 -	0.02	783,916	784,479	1.0
0.02 -	0.03	56,020	840,499	1.1
0.03 -	0.04	236,645	1,077,144	1.4
0.04 -	0.05	22,179	1,099,323	1.4
0.05 -	0.10	2,404,006	3,503,329	4.4
0.10 -	0.15	2,412,056	5,915,385	7.5
0.15 -	0.20	901,034	6,816,419	8.6
0.20 -	0.25	6,914,516	13,730,935	17.3
0.25 -	0.30	854,309	14,585,244	18.4
0.30 -	0.35	946,952	15,532,196	19.6
0.35 -	0.40	565,432	16,097,628	20.3
0.40 -	0.45	1,265,831	17,363,456	21.9
0.45 -	0.50	330,348	17,693,792	22.3
0.50 -	0.60	1,437,234	19,131,040	24.1
0.60 -	0.70	1,450,669	20,581,696	26.0
0.70 -	0.80	2,531,054	23,112,752	29.2
0.80 -	0.90	4,988,900	28,101,664	35.5
0.90 -	1.00	907,933	29,009,584	36.6
1.00 -	2.00	12,833,145	41,842,736	52.8
2.00 -	3.00	8,523,534	50,366,272	63.6
3.00 -	4.00	3,342,495	53,708,768	67.8
4.00 -	5.00	3,463,827	57,172,592	72.1
5.00 -	10.00	7,508,712	64,681,296	81.6
10.00 -	15.00	3,048,209	67,729,504	85.5
15.00 -	20.00	1,529,465	69,258,976	87.4
20.00 -	25.00	1,642,838	70,901,808	89.5
25.00 -	30.00	611,830	71,513,648	90.2
30.00 -	35.00	700,960	72,214,608	91.1
35.00 -	40.00	460,736	72,675,344	91.7
40.00 -	45.00	497,426	73,172,768	92.3
45.00 -	50.00	198,506	73,371,280	92.6
50.00 -	55.00	218,484	73,589,760	92.9
55.00 -	60.00	118,619	73,708,368	93.0
60.00 -	65.00	169,992	73,878,368	93.2
65.00 -	70.00	114,860	73,993,232	93.4
70.00 -	75.00	112,654	74,105,888	93.5
75.00 -	80.00	79,993	74,185,872	93.6
80.00 -	85.00	415,641	74,601,520	94.1
85.00 -	90.00	104,383	74,705,904	94.3
90.00 -	95.00	72,293	74,778,192	94.4
95.00 -	100.00	51,702	74,829,888	94.4
100.00 -	110.00	271,855	75,101,744	94.8
110.00 -	120.00	175,862	75,277,616	95.0
120.00 -	130.00	194,937	75,472,592	95.2
130.00 -	140.00	47,664	75,520,256	95.3
140.00 -	150.00	37,508	75,557,760	95.3
150.00 -	160.00	71,841	75,629,600	95.4
160.00 -	170.00	2,368,111	77,997,712	98.4
170.00 -	180.00	38,527	78,036,240	98.5
180.00 -	190.00	123,050	78,159,296	98.6
190.00 -	200.00	31,165	78,190,464	98.7
210.00 -	300.00	896,356	79,086,816	99.8
301.00 -	400.00	94,995	79,181,808	99.9
401.00 -	500.00	23,678	79,205,488	99.9
Over 500.00		41,345	79,246,832	100.0

Source:

Lawrence G. Regan, et al, Research Analysis Corporation, Economic Use of Military Airlift and Sealift for Overseas Shipment in Peacetime, Volume 1, January 1969, unpublished supporting table for Figure 15, p. 69.

TABLE D-4

COST INPUTS USED IN DETERMINING ECONOMIC RETENTION LEVEL

Cost Description	Cost Symbol	Values Used		
Storage Cost	S	.01	.04	
Deterioration Rate	d	.02	.05	.15
Obsolescence Rate	θ	.02	.05	.15
Loss Rate	L	.01	.02	.05
Cost of Money	i	.10		

Note:

These cost values were used in all possible combinations in Tables 5 and 7 of the report.

APPENDIX E

TRANSFER LEVEL: EXPRESSED IN MULTIPLES OF Q

This appendix contains six tables showing the amount of stock in the transfer level(TL), expressed in multiples of economic order quantity (Q) above the normal maximum stock on hand (safety level plus Q). Optimum TL equals safety level plus Q plus the quantity shown in the tables.

The tables are for the average cost case and are arranged in the following order: lower bound (Q/4) TL formula and upper bound (Q/2) formula for land, sea, and air transportation modes. The formulas are derived in Appendix C.

TABLE E-1

TRANSFER LEVEL
LAND TRANSPORTATION - AVG COST CASE
EXPRESSED IN MULTIPLES OF Q ABOVE NORMAL MAXIMUM
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
10	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
100	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3
1,000	0.9	0.6	0.4	0.3	0.3	0.3	0.3	0.3
10,000	2.3	1.3	0.7	0.5	0.4	0.3	0.3	0.3
100,000	6.7	3.5	1.5	0.9	0.6	0.4	0.3	0.3
1,000,000	20.7	10.5	4.3	2.3	1.3	0.7	0.5	0.3

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.010 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE E-2

TRANSFER LEVEL
SEA TRANSPORTATION - AVG COST CASE
EXPRESSED IN MULTIPLES OF Q ABOVE NORMAL MAXIMUM
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
10	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3
100	0.9	0.6	0.4	0.3	0.3	0.3	0.3	0.3
1,000	2.3	1.3	0.7	0.5	0.4	0.3	0.3	0.3
10,000	6.7	3.5	1.5	0.9	0.6	0.4	0.3	0.3
100,000	20.7	10.5	4.3	2.3	1.3	0.7	0.5	0.3
1,000,000	64.8	32.5	13.2	6.7	3.5	1.5	0.9	0.3

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
$ (SHIPPING COST) = $ 0.050 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

TABLE E-3

TRANSFER LEVEL
AIR TRANSPORTATION - AVG COST CASE
EXPRESSED IN MULTIPLES OF Q ABOVE NORMAL MAXIMUM
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	0.7	0.5	0.3	0.3	0.3	0.3	0.3	0.3
10	1.7	1.0	0.5	0.4	0.3	0.3	0.3	0.3
100	4.8	2.5	1.2	0.7	0.5	0.3	0.3	0.3
1,000	14.5	7.4	3.1	1.7	1.0	0.5	0.4	0.3
10,000	45.4	22.8	9.3	4.8	2.5	1.2	0.7	0.3
100,000	143.1	71.7	28.8	14.5	7.4	3.1	1.7	0.4
1,000,000	452.1	226.2	90.6	45.4	22.8	9.3	4.8	0.7

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR
S (SHIPPING COST) = $ 0.350 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

TABLE E-4

TRANSFER LEVEL
LAND TRANSPORTATION - AVG COST CASE
EXPRESSED IN MULTIPLES OF Q ABOVE NORMAL MAXIMUM
(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
100	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5
1,000	1.8	1.1	0.8	0.6	0.6	0.5	0.5	0.5
10,000	4.6	2.5	1.3	0.9	0.7	0.6	0.5	0.5
100,000	13.4	7.0	3.1	1.8	1.1	0.8	0.6	0.5
1,000,000	41.3	20.9	8.7	4.6	2.5	1.3	0.9	0.5

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.010 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE E-5

TRANSFER LEVEL
SEA TRANSPORTATION - AVG COST CASE
EXPRESSED IN MULTIPLES OF Q ABOVE NORMAL MAXIMUM
(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
10	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.5
100	1.8	1.1	0.8	0.6	0.6	0.5	0.5	0.5
1,000	4.6	2.5	1.3	0.9	0.7	0.6	0.5	0.5
10,000	13.4	7.0	3.1	1.8	1.1	0.8	0.6	0.5
100,000	41.3	20.9	8.7	4.6	2.5	1.3	0.9	0.5
1,000,000	129.6	65.0	26.3	13.4	7.0	3.1	1.8	0.6

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.050 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

TABLE E-6

TRANSFER LEVEL
AIR TRANSPORTATION - AVG COST CASE
EXPRESSED IN MULTIPLES OF Q ABOVE NORMAL MAXIMUM
(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	1.4	1.0	0.7	0.6	0.5	0.5	0.5	0.5
10	3.4	1.9	1.1	0.8	0.6	0.6	0.5	0.5
100	9.5	5.0	2.3	1.4	1.0	0.7	0.6	0.5
1,000	29.1	14.8	6.2	3.4	1.9	1.1	0.8	0.5
10,000	90.9	45.7	18.6	9.5	5.0	2.3	1.4	0.6
100,000	286.3	143.4	57.7	29.1	14.8	6.2	3.4	0.8
1,000,000	904.2	452.3	181.2	90.9	45.7	18.6	9.5	1.4

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST)= $ 0.350 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

APPENDIX F

TRANSFER LEVEL: EXPRESSED IN NUMBER OF MONTHS SUPPLY

This appendix contains 18 tables showing the amount of stock in the transfer level(TL), expressed in number of months supply above the normal maximum stock on hand (safety level (SL) plus economic quantity (Q)).

The tables are arranged in the following order: six tables each for land, sea, and air transportation modes with a lower bound (Q/4) TL formula, then upper bound (Q/2) TL formula for the low, average, and high cost cases. The TL formulas are explained in Appendix C.

TABLE F-1

TRANSFER LEVEL
LAND TRANSPORTATION - LOW COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	18.5	18.1	17.9	17.8	17.8	17.8	17.8	17.7
10	6.4	6.0	5.8	5.7	5.6	5.6	5.6	5.6
100	2.5	2.1	1.9	1.8	1.8	1.8	1.8	1.8
1,000	1.3	0.9	0.7	0.6	0.6	0.6	0.6	0.6
10,000	0.9	0.6	0.3	0.3	0.2	0.2	0.2	0.2
100,000	0.8	0.4	0.2	0.1	0.1	0.1	0.1	0.1
1,000,000	0.8	0.4	0.2	0.1	0.1	0.0	0.0	0.0

WHERE:

H (HOLDING COST) = 0.40 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.005 PER POUND.
F (FIXED COST) = $ 7.00 PER SHIPMENT.

TABLE F-2

TRANSFER LEVEL
LAND TRANSPORTATION - AVG COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	26.5	25.5	24.9	24.7	24.6	24.5	24.5	24.5
10	9.7	8.7	8.1	7.9	7.8	7.8	7.8	7.7
100	4.4	3.4	2.8	2.6	2.5	2.5	2.5	2.5
1,000	2.8	1.8	1.2	1.0	0.9	0.8	0.8	0.8
10,000	2.2	1.2	0.6	0.4	0.3	0.3	0.3	0.2
100,000	2.1	1.1	0.5	0.3	0.2	0.1	0.1	0.1
1,000,000	2.0	1.0	0.4	0.2	0.1	0.1	0.0	0.0

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.010 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE F-3

TRANSFER LEVEL
LAND TRANSPORTATION - HIGH COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	41.2	39.0	37.6	37.2	37.0	36.8	36.8	36.7
10	16.1	13.9	12.5	12.1	11.8	11.7	11.7	11.6
100	8.2	5.9	4.6	4.1	3.9	3.8	3.7	3.7
1,000	5.7	3.4	2.1	1.6	1.4	1.3	1.2	1.2
10,000	4.9	2.6	1.3	0.8	0.6	0.5	0.4	0.4
100,000	4.6	2.4	1.0	0.6	0.3	0.2	0.2	0.1
1,000,000	4.5	2.3	0.9	0.5	0.3	0.1	0.1	0.0

WHERE:

H (HOLDING COST) = 0.20 OF UNIT PRICE PER YEAR.
$ (SHIPPING COST) = $ 0.015 PER POUND.
F (FIXED COST) = $15.00 PER SHIPMENT.

TABLE F-4

TRANSFER LEVEL
LAND TRANSPORTATION - LOW COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	37.0	36.2	35.8	35.6	35.6	35.5	35.5	35.5
10	12.7	12.0	11.5	11.4	11.3	11.3	11.2	11.2
100	5.0	4.3	3.8	3.7	3.6	3.6	3.6	3.6
1,000	2.6	1.9	1.4	1.3	1.2	1.2	1.1	1.1
10,000	1.9	1.1	0.7	0.5	0.4	0.4	0.4	0.4
100,000	1.6	0.9	0.4	0.3	0.2	0.1	0.1	0.1
1,000,000	1.5	0.8	0.3	0.2	0.1	0.1	0.1	0.0

WHERE:

H (HOLDING COST) = 0.40 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.005 PER POUND.
F (FIXED COST) = $ 7.00 PER SHIPMENT.

TABLE F-5

TRANSFER LEVEL
LAND TRANSPORTATION - AVG COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q

(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	53.0	51.0	49.8	49.4	49.2	49.1	49.0	49.0
10	19.5	17.5	16.3	15.9	15.7	15.6	15.5	15.5
100	8.9	6.9	5.7	5.3	5.1	5.0	4.9	4.9
1,000	5.5	3.5	2.3	1.9	1.7	1.6	1.6	1.6
10,000	4.5	2.5	1.3	0.9	0.7	0.6	0.5	0.5
100,000	4.2	2.2	1.0	0.6	0.4	0.2	0.2	0.2
1,000,000	4.0	2.0	0.8	0.4	0.2	0.1	0.1	0.1

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST)= $ 0.010 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE F-6

TRANSFER LEVEL
LAND TRANSPORTATION - HIGH COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	82.5	78.0	75.3	74.4	73.9	73.7	73.6	73.5
10	32.2	27.7	25.0	24.1	23.7	23.4	23.3	23.2
100	16.3	11.8	9.1	8.2	7.8	7.5	7.4	7.4
1,000	11.3	6.8	4.1	3.2	2.8	2.5	2.4	2.3
10,000	9.7	5.2	2.5	1.6	1.2	0.9	0.8	0.7
100,000	9.2	4.7	2.0	1.1	0.7	0.4	0.3	0.2
1,000,000	9.1	4.6	1.9	1.0	0.5	0.3	0.2	0.1

WHERE:

H (HOLDING COST) = 0.20 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.015 PER POUND.
F (FIXED COST) = $15.00 PER SHIPMENT.

TABLE F-7

TRANSFER LEVEL
SEA TRANSPORTATION - LOW COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	24.2	22.7	21.8	21.5	21.4	21.3	21.2	21.2
10	9.7	8.2	7.3	7.0	6.9	6.8	6.7	6.7
100	5.1	3.6	2.7	2.4	2.3	2.2	2.2	2.1
1,000	3.7	2.2	1.3	1.0	0.8	0.7	0.7	0.7
10,000	3.2	1.7	0.8	0.5	0.4	0.3	0.2	0.2
100,000	3.1	1.6	0.7	0.4	0.2	0.1	0.1	0.1
1,000,000	3.0	1.5	0.6	0.3	0.2	0.1	0.1	0.0

WHERE:

H (HOLDING COST) = 0.40 OF UNIT PRICE PER YEAR.
S (SHIPPING COST)= $ 0.020 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE F-8

TRANSFER LEVEL
SEA TRANSPORTATION - AVG COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	48.7	43.7	40.7	39.7	39.2	38.9	38.8	38.7
10	22.2	17.2	14.2	13.2	12.7	12.4	12.3	12.3
100	13.9	8.9	5.9	4.9	4.4	4.1	4.0	3.9
1,000	11.2	6.2	3.2	2.2	1.7	1.4	1.3	1.2
10,000	10.4	5.4	2.4	1.4	0.9	0.6	0.5	0.4
100,000	10.1	5.1	2.1	1.1	0.6	0.3	0.2	0.1
1,000,000	10.0	5.0	2.0	1.0	0.5	0.2	0.1	0.0

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.050 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

TABLE F-9

TRANSFER LEVEL
SEA TRANSPORTATION - HIGH COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	91.1	79.1	71.9	69.5	68.3	67.6	67.3	67.1
10	45.2	33.2	26.0	23.6	22.4	21.7	21.5	21.2
100	30.7	18.7	11.5	9.1	7.9	7.2	6.9	6.7
1,000	26.1	14.1	6.9	4.5	3.3	2.6	2.4	2.1
10,000	24.7	12.7	5.5	3.1	1.9	1.2	0.9	0.7
100,000	24.2	12.2	5.0	2.6	1.4	0.7	0.5	0.2
1,000,000	24.1	12.1	4.9	2.5	1.3	0.5	0.3	0.1

WHERE:

H (HOLDING COST) = 0.20 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.080 PER POUND.
F (FIXED COST) = $50.00 PER SHIPMENT.

TABLE F-10

TRANSFER LEVEL
SEA TRANSPORTATION - LOW COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	48.4	45.4	43.6	43.0	42.7	42.5	42.5	42.4
10	19.4	16.4	14.6	14.0	13.7	13.5	13.5	13.4
100	10.2	7.2	5.4	4.8	4.5	4.4	4.3	4.2
1,000	7.3	4.3	2.5	1.9	1.6	1.5	1.4	1.3
10,000	6.4	3.4	1.6	1.0	0.7	0.5	0.5	0.4
100,000	6.1	3.1	1.3	0.7	0.4	0.3	0.2	0.1
1,000,000	6.0	3.0	1.2	0.6	0.3	0.2	0.1	0.0

WHERE:

H (HOLDING COST) = 0.40 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.020 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE F-11

TRANSFER LEVEL
SEA TRANSPORTATION - AVG COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q

(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	97.5	87.5	81.5	79.5	78.5	77.9	77.7	77.5
10	44.5	34.5	28.5	26.5	25.5	24.9	24.7	24.5
100	27.7	17.7	11.7	9.7	8.7	8.1	7.9	7.8
1,000	22.4	12.4	6.4	4.4	3.4	2.8	2.6	2.5
10,000	20.8	10.8	4.8	2.8	1.8	1.2	1.0	0.8
100,000	20.2	10.2	4.2	2.2	1.2	0.6	0.4	0.3
1,000,000	20.1	10.1	4.1	2.1	1.1	0.5	0.3	0.1

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.050 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

TABLE F-12

TRANSFER LEVEL
SEA TRANSPORTATION - HIGH COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	182.2	158.2	143.8	139.0	136.6	135.1	134.6	134.2
10	90.4	66.4	52.0	47.2	44.8	43.4	42.9	42.5
100	61.4	37.4	23.0	18.2	15.8	14.4	13.9	13.5
1,000	52.2	28.2	13.8	9.0	6.6	5.2	4.7	4.3
10,000	49.3	25.3	10.9	6.1	3.7	2.3	1.8	1.4
100,000	48.4	24.4	10.0	5.2	2.8	1.4	0.9	0.5
1,000,000	48.1	24.1	9.7	4.9	2.5	1.1	0.6	0.2

WHERE:

H (HOLDING COST) = 0.20 OF UNIT PRICE PER YEAR.
S (SHIPPING COST)= $ 0.080 PER POUND.
F (FIXED COST) = $50.00 PER SHIPMENT.

TABLE F-13

TRANSFER LEVEL
AIR TRANSPORTATION - LOW COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	51.2	36.2	27.2	24.2	22.7	21.8	21.5	21.2
10	36.7	21.7	12.7	9.7	8.2	7.3	7.0	6.7
100	32.1	17.1	8.1	5.1	3.6	2.7	2.4	2.2
1,000	30.7	15.7	6.7	3.7	2.2	1.3	1.0	0.7
10,000	30.2	15.2	6.2	3.2	1.7	0.8	0.5	0.2
100,000	30.1	15.1	6.1	3.1	1.6	0.7	0.4	0.1
1,000,000	30.0	15.0	6.0	3.0	1.5	0.6	0.3	0.1

WHERE:

H (HOLDING COST) = 0.40 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.200 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE F-14

TRANSFER LEVEL
AIR TRANSPORTATION - AVG COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	108.7	73.7	52.7	45.7	42.2	40.1	39.4	38.8
10	82.2	47.2	26.2	19.2	15.7	13.6	12.9	12.3
100	73.9	38.9	17.9	10.9	7.4	5.3	4.6	3.9
1,000	71.2	36.2	15.2	8.2	4.7	2.6	1.9	1.3
10,000	70.4	35.4	14.4	7.4	3.9	1.8	1.1	0.5
100,000	70.1	35.1	14.1	7.1	3.6	1.5	0.8	0.2
1,000,000	70.0	35.0	14.0	7.0	3.5	1.4	0.7	0.1

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST)= $ 0.350 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

TABLE F-15

TRANSFER LEVEL
AIR TRANSPORTATION - HIGH COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q
(Q/4)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	217.1	142.1	97.1	82.1	74.6	70.1	68.6	67.2
10	171.2	96.2	51.2	36.2	28.7	24.2	22.7	21.4
100	156.7	81.7	36.7	21.7	14.2	9.7	8.2	6.9
1,000	152.1	77.1	32.1	17.1	9.6	5.1	3.6	2.3
10,000	150.7	75.7	30.7	15.7	8.2	3.7	2.2	0.8
100,000	150.2	75.2	30.2	15.2	7.7	3.2	1.7	0.4
1,000,000	150.1	75.1	30.1	15.1	7.6	3.1	1.6	0.2

WHERE:

H (HOLDING COST) = 0.20 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.500 PER POUND.
F (FIXED COST) = $50.00 PER SHIPMENT.

TABLE F-16

TRANSFER LEVEL
AIR TRANSPORTATION - LOW COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q

(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	102.4	72.4	54.4	48.4	45.4	43.6	43.0	42.5
10	73.4	43.4	25.4	19.4	16.4	14.6	14.0	13.5
100	64.2	34.2	16.2	10.2	7.2	5.4	4.8	4.3
1,000	61.3	31.3	13.3	7.3	4.3	2.5	1.9	1.4
10,000	60.4	30.4	12.4	6.4	3.4	1.6	1.0	0.5
100,000	60.1	30.1	12.1	6.1	3.1	1.3	0.7	0.2
1,000,000	60.0	30.0	12.0	6.0	3.0	1.2	0.6	0.1

WHERE:

H (HOLDING COST) = 0.40 OF UNIT PRICE PER YEAR.
S (SHIPPING COST) = $ 0.200 PER POUND.
F (FIXED COST) = $10.00 PER SHIPMENT.

TABLE F-17

TRANSFER LEVEL
AIR TRANSPORTATION - AVG COST CASF
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q

(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	217.5	147.5	105.5	91.5	84.5	80.3	78.9	77.6
10	164.5	94.5	52.5	38.5	31.5	27.3	25.9	24.6
100	147.7	77.7	35.7	21.7	14.7	10.5	9.1	7.9
1,000	142.4	72.4	30.4	16.4	9.4	5.2	3.8	2.6
10,000	140.8	70.8	28.8	14.8	7.8	3.6	2.2	0.9
100,000	140.2	70.2	28.2	14.2	7.2	3.0	1.6	0.4
1,000,000	140.1	70.1	28.1	14.1	7.1	2.9	1.5	0.2

WHERE:

H (HOLDING COST) = 0.30 OF UNIT PRICE PER YEAR.
S (SHIPPING COST)= $ 0.350 PER POUND.
F (FIXED COST) = $25.00 PER SHIPMENT.

TABLE F-18

TRANSFER LEVEL
AIR TRANSPORTATION - HIGH COST CASE
EXPRESSED IN NUMBER OF MONTHS SUPPLY ABOVE S + Q

(Q/2)

ANNUAL DEMAND IN DOLLARS	UNIT PRICE PER POUND (IN DOLLARS)							
	0.10	0.20	0.50	1.00	2.00	5.00	10.00	100.00
1	434.2	284.2	194.2	164.2	149.2	140.2	137.2	134.5
10	342.4	192.4	102.4	72.4	57.4	48.4	45.4	42.7
100	313.4	163.4	73.4	43.4	28.4	19.4	16.4	13.7
1,000	304.2	154.2	64.2	34.2	19.2	10.2	7.2	4.5
10,000	301.3	151.3	61.3	31.3	16.3	7.3	4.3	1.6
100,000	300.4	150.4	60.4	30.4	15.4	6.4	3.4	0.7
1,000,000	300.1	150.1	60.1	30.1	15.1	6.1	3.1	0.4

WHERE:

H (HOLDING COST) = 0.20 OF UNIT PRICE PER YEAR.
S (SHIPPING COST)= $ 0.500 PER POUND.
F (FIXED COST) = $50.00 PER SHIPMENT.

APPENDIX G

FORMULAS FOR THE DIFFERENCE IN COST BETWEEN AN ARBITRARY APPROXIMATION OF THE TRANSFER LEVEL AND THE CALCULATED OPTIMUM

The equation derived below can be used to calculate the increased cost, I_{ac}, that would result from using an arbitrary transfer level, T_a, rather than the calculated optimum, T_c. Some of the symbols defined in Appendix C are used, and in addition,

Let:

K_a = extra cost to hold T_a instead of N (not netted for shipping cost change

I_{ac} = increase in cost by holding T_a instead of T_c

M_a = amount of stock added to the average requirement level at an arbitrary transfer level, T_a, expressed as a multiple of Q, so that $M_a = (T_a - N)/Q$.

T_a = an arbitrarily defined estimate of T_c

Y_{ac} = the added stock, in years supply, between M_a and M_c, such that $Y_{ac} = (M_a - M_c)Q/D$

The excess cost, $\underline{I}_{ac}$, of holding an amount of inventory T_a, instead of the lower bound amount $\underline{T}_c$, with associated upper bound costs $\bar{K}_a$ and $\bar{K}_c$, is

(G1) $$\underline{I}_{ac} = \bar{K}_a - \bar{K}_c$$

Substituting equation C4 from Appendix C for $\bar{K}_a$ and $\bar{K}_c$,

$$\underline{I}_{ac} = \frac{HV(T_a-N)^2}{D} - \left(\frac{F}{Q}+WS\right)\left(T_a-N\right) - \frac{HV(\underline{T}_c-N)^2}{D} + \left(\frac{F}{Q}+WS\right)\left(\underline{T}_c-N\right)$$

$$(G2) \qquad = \frac{HV}{D}\left[(T_a-N)^2 - (\underline{T}_c-N)^2\right] - \left(\frac{F}{Q}+WS\right)\left[(T_a-N) - (\underline{T}_c-N)\right]$$

Substituting $\underline{T}_c-N = \underline{M}_c Q$; $T_a-N = M_a Q$; $2FD/HV = Q^2$; and $W = A/BD$, and simplifying,

$$\underline{I}_{ac} = \left(2F/Q^2\right)\left(M^2_a Q^2 - \underline{M}^2_c Q^2\right) - \left(\frac{F}{Q} + \frac{AS}{BD}\right)\left(M_a Q - \underline{M}_c Q\right)$$

$$(G3) \qquad \underline{I}_{ac} = 2F\left(M^2_a - \underline{M}^2_c\right) - \left(F + \frac{ASQ}{BD}\right)\left(M_a - \underline{M}_c\right)$$

The corresponding difference in number of years' supply, $\underline{Y}_{ac}$, held in stock, if T_a is held instead of $\underline{T}_c$ is

$$(G4) \qquad \underline{Y}_{ac} = (T_a - \underline{T}_c)/D$$

with $\underline{T}_c$ determined by equation C6.

The counterpart of equation G3, for the difference in costs, $\bar{I}_{ac}$; associated with the lower bound costs at T_a and $\bar{T}_c$, is similarly derived, resulting only in removal of the linear factor "2" from the first term of equation G3.

Similarly, the difference in years supply between T_a and $\bar{T}_c$, is

$$(G5) \qquad \bar{Y}_{ac} = (T_a - \bar{T}_c)/D$$

APPENDIX H

NET DOLLAR DIFFERENCE BETWEEN OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE

There are six tables in this appendix. The first three tables are low, average, and high cost cases for the lower bound (Q/4) transfer level formula. The last three tables are low, average, and high cost cases for the upper bound (Q/2) transfer level formula.

The lower and upper bound formulas are explained in detail in Appendix C. Inputs for the three cost cases are described in Appendix D. The formula for determining the net dollar differences in these tables is explained in Appendix G.

TABLE H-1

NET DOLLAR COST DIFFERENCE BETWEEN
OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE
LOW COST CASE (Q/4)

UNIT PRICE PER POUND	ANNUAL DEMAND $10	$100	$1,000	$10,000	$100,000
			OST = 1 Month of RO		
Land Transportation					
$ .50/lb	1	0	0	13	175
$ 2.00/lb	1	0	0	17	228
Sea Transportation					
$ .50/lb	1	1	0	1	31
$ 2.00/lb	1	0	0	11	170
Air Transportation					
$ 5.00/lb	1	1	0	1	31
$10.00/lb	1	1	0	7	111
			OST = 4 Months of RO		
Land Transportation					
$ .50/lb	0	1	30	375	3998
$ 2.00/lb	0	1	32	398	4239
Sea Transportation					
$ .50/lb	0	0	21	282	3086
$ 2.00/lb	0	1	28	368	3975
Air Transportation					
$ 5.00/lb	0	0	21	282	3086
$10.00/lb	0	1	25	338	3666

TABLE H-2

NET DOLLAR COST DIFFERENCE BETWEEN
OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE
AVERAGE COST CASE (Q/4)

UNIT PRICE PER POUND	ANNUAL DEMAND $10	$100	$1,000	$10,000	$100,000
OST = 1 Month of RO					
Land Transportation					
$ .50/lb	1	1	0	3	57
$ 2.00/lb	1	1	0	9	141
Sea Transportation					
$ .50/lb	4	5	10	40	262
$ 2.00/lb	3	2	1	0	30
Air Transportation					
$ 5.00/lb	3	4	5	13	57
$10.00/lb	3	3	2	0	7
OST = 4 Months of RO					
Land Transportation					
$ .50/lb	0	0	10	235	2585
$ 2.00/lb	0	0	20	278	3044
Sea Transportation					
$ .50/lb	2	1	1	54	734
$ 2.00/lb	2	0	11	202	2377
Air Transportation					
$ 5.00/lb	2	0	4	102	1279
$10.00/lb	2	0	9	177	2103

TABLE H-3

NET DOLLAR COST DIFFERENCE BETWEEN
OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE
HIGH COST CASE (Q/4)

UNIT PRICE PER POUND	ANNUAL DEMAND $10	$100	$1,000	$10,000	$100,000
OST = 1 Month of RO					
Land Transportation					
$ .50/lb	2	2	2	1	0
$ 2.00/lb	2	1	0	2	60
Sea Transportation					
$ .50/lb	9	15	49	278	2236
$ 2.00/lb	6	7	7	11	24
Air Transportation					
$ 5.00/lb	7	11	24	99	680
$10.00/lb	7	7	10	19	70
OST = 4 Months of RO					
Land Transportation					
$ .50/lb	1	0	5	104	1237
$ 2.00/lb	1	0	9	161	1859
Sea Transportation					
$ .50/lb	7	8	12	30	142
$ 2.00/lb	5	2	1	63	930
Air Transportation					
$ 5.00/lb	6	5	2	2	86
$10.00/lb	5	2	0	46	727

TABLE H-4

NET DOLLAR COST DIFFERENCE BETWEEN
OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE
LOW COST CASE (Q/2)

UNIT PRICE PER POUND	ANNUAL DEMAND $10	$100	$1,000	$10,000	$100,000
	OST = 1 Month of RO				
Land Transportation					
$ .50/lb	2	1	0	2	48
$ 2.00/lb	1	1	0	5	92
Sea Transportation					
$ .50/lb	3	3	3	5	16
$ 2.00/lb	2	2	1	1	44
Air Transportation					
$ 5.00/lb	3	3	3	5	16
$10.00/lb	2	2	1	0	10
	OST = 4 Months of RO				
Land Transportation					
$ .50/lb	1	0	9	155	1788
$ 2.00/lb	1	0	11	177	2019
Sea Transportation					
$ .50/lb	2	0	3	78	987
$ 2.00/lb	1	0	8	149	1766
Air Transportation					
$ 5.00/lb	2	0	3	78	987
$10.00/lb	1	0	6	123	1481

TABLE H-5

NET DOLLAR COST DIFFERENCE BETWEEN
OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE
AVERAGE COST CASE (Q/2)

UNIT PRICE PER POUND	ANNUAL DEMAND $10	$100	$1,000	$10,000	$100,000
			OST = 1 Month of RO		
Land Transportation					
$ .50/lb	2	2	2	1	0
$ 2.00/lb	2	2	1	1	43
Sea Transportation					
$ .50/lb	8	12	31	148	1097
$ 2.00/lb	6	6	6	6	6
Air Transportation					
$ 5.00/lb	7	9	19	69	436
$10.00/lb	6	7	8	14	43
			OST = 4 Months of RO		
Land Transportation					
$ .50/lb	2	0	3	77	966
$ 2.00/lb	1	0	5	114	1384
Sea Transportation					
$ .50/lb	6	6	6	6	6
$ 2.00/lb	5	2	0	52	791
Air Transportation					
$ 5.00/lb	6	4	2	2	95
$10.00/lb	5	3	0	35	578

TABLE H-6

NET DOLLAR COST DIFFERENCE BETWEEN
OPTIMUM TRANSFER LEVEL AND REQUISITIONING OBJECTIVE
HIGH COST CASE (Q/2)

UNIT PRICE PER POUND	ANNUAL DEMAND $10	$100	$1,000	$10,000	$100,000
			OST = 1 Month of RO		
Land Transportation					
$ .50/lb	4	5	7	16	74
$ 2.00/lb	4	3	2	0	7
Sea Transportation					
$ .50/lb	18	34	115	686	5655
$ 2.00/lb	13	15	22	52	231
Air Transportation					
$ 5.00/lb	16	24	59	279	2043
$10.00/lb	14	17	27	78	408
			OST = 4 Months of RO		
Land Transportation					
$ .50/lb	3	2	0	15	269
$ 2.00/lb	3	1	1	55	764
Sea Transportation					
$ .50/lb	16	25	67	335	2520
$ 2.00/lb	12	10	5	0	96
Air Transportation					
$ 5.00/lb	14	17	27	78	408
$10.00/lb	12	11	7	1	23